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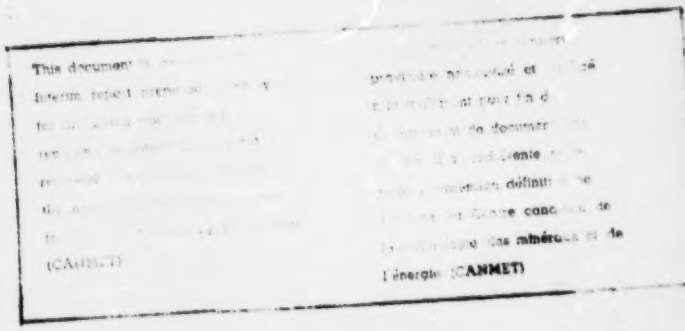
CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

PHYSICAL METALLURGY RESEARCH LABORATORIES ANNUAL REPORT FY 1981-82



74 pp

MINERALS AND ENERGY RESEARCH PROGRAMS

ERP/MRP/PMRL 82-39(TR)

MICROMEDIA

PHYSICAL METALLURGY RESEARCH LABORATORIES

ANNUAL REPORT FY 1981-82

Compiled by C. Dixon

APRIL 1982

MINERALS AND ENERGY RESEARCH PROGRAMS

ERP/MRP/PMRL 82-31(TR)

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FOREWORD

During the past year, the expanded responsibilities and additional resources allocated to PMRL under the National Energy Program have provided the impetus for a measure of renewal after a decade of restraint and retrenchment. The addition of a few young researchers to staff and the replacement of the most antiquated apparatus by modern equipment has done much to bring the spirit and productivity of the organization to a high level.

In 1981-82, the operating budget of PMRL in the Minerals and Earth Sciences Program was $4.4 m, with 131 person-years, and $0.76 m in the National Energy Program, with 8 new positions. The budget for external research contracts grew to $1.37 m, mostly through new support from the National Energy Program. Indeed the size of the contract program has now put severe strains on existing staff, since PMRL has found that external contracts are most effective when they are associated with research in-house. Accordingly, further expansion of contracts should be coupled with corresponding increases in staff.

PMRL continued to put great emphasis on the transfer of technology developed within its laboratories to Canadian industry. Substantial progress was made toward commercializing the CANCOAT system for in-situ casting of hard facings, the CANMET portable X-ray stress diffractometer, CANMET degradable sand binder systems, and CANMET fluidized-bed heat-treatment technology.

The past year saw significant shifts in emphasis. In the Minerals Research Program, research diminished on materials for automobiles and rails but increased on marine materials, to meet a demonstrable need for the use of improved materials in ships for arctic waters. In the Energy Research Program, a major effort was launched on materials research for offshore structures, largely supported by the National Energy Program.

W.H. Erickson

AVANT-PROPOS

Au cours de l'année dernière, l'accroissement des responsabilités et des ressources allouées aux L.R.M.P. sous l'égide du Programme énergétique national a stimulé un intérêt pour le renouveau, après une décenie de contraintes et de restrictions. L'addition au personnel de quelques jeunes chercheurs, de même que le remplacement des appareils les plus désuets par de plus modernes, ont largement contribué à élever l'esprit et la productivité de notre organisation à de plus hauts sommets.

Au cours des années 1981-82, le budget d'exploitation accordé au Programme des Minéraux et Sciences de la Terre par les L.R.M.P. s'élevait à 4,4 millions de dollars, avec 131 années-personnes. Celui du Programme énergétique national se chiffrait à 0,76 millions, avec 8 nouveaux postes. Quant au budget des contrats de recherche effectuée à l'extérieur, il s'est vu augmenter jusqu'à 1,37 millions, en grande partie à cause du nouvel appui du Programme énergétique national. De fait, l'étendue du programme de contrats pose maintenant de sérieuses contraintes au personnel existant, puisque les L.R.M.P. ont constaté l'efficacité accrue des contrats de recherche à l'extérieur lorsque ces derniers sont jumelés à des projets de recherche "maison". Ainsi, l'augmentation des contrats externes devrait être accompagnée proportionnellement de l'augmentation du personnel interne.

Les L.R.M.P. ont continué de mettre l'accent sur le transfert de la technologie développée dans ses laboratoires, à l'industrie canadienne. On a fait des progrès considérables vers la commercialisation du système CANCOAT relativement à la fonte sur les lieux de revêtements durs, du diffractomètre portatif de CANMET pour mesurer la tension par rayons X, des systèmes de liant pour sable dégradable, et de la technologie de CANMET concernant le traitement thermique par lit fluidisé.

Au cours de l'année précédente, on a pu constater de façon considérable un changement d'emphase. Dans le cadre du Programme de recherche sur les minéraux, on a diminué les recherches concernant les matériaux pour les rails et les automobiles, au profit de celles sur les matériaux marins, afin de pourvoir à un besoin évident de matériaux améliorés pour les bateaux circulant dans les eaux arctiques.

Dans le cadre du Programme de recherche énergétique, les efforts ont été consacrés à la recherche sur les matériaux pour les structures au large des côtes, efforts hautement appuyés par le Programme énergétique national.

W.H. Erickson

HIGHLIGHTS

MINERALS RESEARCH PROGRAM

In co-operation with a major Canadian steel producer, PMRL/CANMET has developed experimental high strength low alloy steels, with titanium and nitrogen additions, that show a three-fold improvement in notch toughness in the weld heat-affected-zone; commercial heats of these steels show a similar improvement.

PMRL has continued to actively promote the rapid transfer of technology developed in its laboratories to industry. Two workshops on grey and ductile iron were attended by some sixty-five foundrymen. Workshops were held in Edmonton, Cambridge, Hamilton, Trois Rivières and Moncton to acquaint cupola operators with the results of the PMRL cupola efficiency survey and with the use of the CANMET cupola handbook and computer software. The second CANMET Rolling Mill Technology seminar attracted over ninety participants from Canadian industry, universities and government.

The laboratories have demonstrated that simulated sections of lean alloy steel rail can be heat treated to exceptionally high hardness ($R_c 44$) in a fluidized bed, without sacrificing toughness; generally high hardness implies low rail wear. A major Canadian rail producer is contemplating the incorporation of this technology in plans for a new shapes mill, that would include rail as one of its products.

In marine materials research, PMRL has evaluated failures in hull steels of Canadian ships recently constructed for arctic service and finds that their fracture toughness is inadequate for the operating temperatures encountered; steels to CSA standards are readily available with adequate fracture resistance at low temperatures. PMRL has worked closely with a Canadian foundry to cast a large complex valve chest in cupro-nickel for the Canadian Navy; in the past, this component has been imported.

ENERGY RESEARCH PROGRAM

An extensive research program to evaluate the material properties of various candidate linepipes has been virtually completed. Significant variations in the microstructure and properties of test specimens taken from different locations within a single section of linepipe emphasize that acceptance standards must specify test locations precisely. For the ductile fracture mode, toughness has been shown to correlate well with an inclusion factor having components of mean inclusion length and mean inclusion spacing. For the cleavage fracture mode, toughness correlates well with the largest polygonal ferrite grain size.

Dents and gouges in linepipe are difficult to avoid in pipelaying operations. Work at PMRL has shown that dents with gentle curvature can be pushed out close to the original contour of the pipe in pressurization tests and that a crack will not initiate either during the pressure test or subsequent fatigue loading.

Sulphide inclusion shape control is commonly practised in steelmaking to improve steel toughness and directional properties. Recently, PMRL researchers have found that the seam weld metal toughness in a spirally-welded pipe with inclusion shape control was less than anticipated; further research will hopefully explain this unexpected result.

PMRL is launching a substantial program of research on materials for offshore structures under the National Energy Program, occasioned by the severe environmental conditions structures will encounter off Canada's east coast and in the Beaufort Sea. A prominent metallurgist, associated with oil and gas developments in the North Sea, briefed PMRL staff of European materials research in this area. Contracts were initiated: (a) to review present standards for steels used for offshore structures, (b) to estimate the potential market for steel plate for offshore structures and arctic vessels, (c) to study the corrosion fatigue of tubular joints for off-shore platforms, (d) to evaluate the suitability of four CSA grades of steel for offshore use, and (e) to design a heavy-section fracture testing machine.

Recently, PMRL used its expertise to advise Petro-Canada on the choice of materials for advanced pressure vessels, justifying the decision of the organization a few years ago to begin research in this field in the face of little outside support.

SPECIAL HONOURS

J.O. Edwards, who retired in 1979 after a career of 31 years with the Physical Metallurgy Research Laboratories, has been awarded the American Foundrymen's Society's (AFS) William H. McFadden Gold Medal for 1982 in recognition of "his research career relating to the Brass and Bronze industry and the promulgation of such technology for the benefit of the operating foundryman". The award is the highest recognition the AFS offers to those who serve the industry.

C.M. Mitchell has been awarded the 1981 Canadian Metal Physics Conference Medal for outstanding service to metal physics in Canada.

R.D. Warda, E.F. Darke, and H.P. Guindon, received the American Foundrymen's Society Methods Division, Best Paper Award 1981 for their paper; "The true thermal efficiencies of thirty cupolas".

K.G. Davis and J.G. Magny received the American Foundrymen's Society Best Paper Award 1981 in the category of Energy Management for their paper "Optimum ladle preheating with gas torches".

CONTENTS

	Page
FOREWORD	1
AVANT-PROPOS	ii
HIGHLIGHTS	iii
SPECIAL HONOURS	iv
PART A. MINERALS RESEARCH PROGRAM	1
360002 - Corrosion of Steels in Soils	1
360011 - Abrasion Resistant Cast-on Coatings	1
360012 - Abrasion Resistant Plate Steels	1
360021 - Weld Mechanics	2
360022 - Repair and Reclamation by Welding	2
360023 - Heat Affected Zone Toughness	2
360031 - Characterization of Weld Defects	3
360041 - Plastic Flow, Fracture, and Stress Analysis	3
360042 - Portable X-ray Stress Diffractometer	4
360051 - Microstructural Effects on Strength and Toughness in Engineering Alloys	4
360052 - Development of Non-Leaded, Free Machining Steel	4
370002 - Technology for the Metal Casting Industry	5
Intercritical Heat Treatment	5
Filters for Ferrous and Non-ferrous Casting	5
Optimum Properties in Magnesium Alloy Sand-Castings	5
Cast-in-place Copper Tubing in Copper Tuyères	5
Cupola Melting Efficiency Survey	6
Grey and Ductile Iron Workshop	7
370003 - Degradable Sand and Core Binders	7
370004 - Continuous Casting of Metals	7
370005 - Permanent Mould Casting	7
Inoculation of Iron Castings Made in Permanent Moulds	7
Cast-to-shape Dies for Permanent Moulds	8
Testing of Die Materials and Die Castings	8
Design and Evaluation of Low Pressure Permanent Mould Test Castings	8
Mathematical Modelling of Heat Flow in Permanent moulds	8
370006 - Electroslag Casting	8
370008 - CANMET Foundry Newsletter	9
370011 - Optimization of Rolling Mill Performance	9
370012 - Influence of Microstructure on Formability	9
370014 - Fluidized Bed Cooling	9
370021 - Heat Treated Rail	10
Thermal Processing	11
Wear	11
370031 - Automotive Materials	11
370041 - Marine Materials	12
370042 - High-Strength Copper Base Alloys for Shipboard Systems	13
Cupro-nickel Casting Alloys	13
Nickel-aluminum Bronzes	13
Propellers for Ice Breakers	14
380012 - Development of Instrumentation and Techniques	14
380021 - Certification of NDT Personnel	14
PART B. ENERGY RESEARCH PROGRAM	15
420501 - Materials for Tar Sands Processing	15
420502 - Pressure Vessels	15
Welding Processes	15
Non-destructive Evaluation	15
Properties of Pressure-Vessel Materials	15
420503 - Welding Process Development	17
420601 - Development and Evaluation of High Strength Steels for Oil and Gas Pipelines	17

CONTENTS (cont'd)

		Page
420602 -	Degradation, Inspection and Repair of Pipelines	18
	Mechanical Damage	18
	Residual Stresses	18
	Corrosion Degradation Mechanisms	18
420603 -	Fabrication of Pipelines	19
	Welding	19
	Fittings	20
420604 -	Fabrication, Performance, Inspection and Repair Technology Development (for Offshore Structures) ...	20
420605 -	Development of Tough Weldable Steels (for Offshore Structures)	20
430901 -	Materials for Coal Handling and Utilization	21
430902 -	Materials for High-Temperature Energy Conversion Processes (NEP)	21
PART C.	PUBLICATIONS, PRESENTATIONS AND REPORTS	23
	Papers Published in Outside Journals and in Conference Proceedings	23
	Presentations	24
	Available PMRL Reports	27
	Internal and Confidential Reports	30
	Declassified Confidential Reports	31
	Reports by Category	31
PART D.	STAFF ACTIVITIES	33
	1981-82 Conference Attendance	33
	Field Trips and Significant Meeting Travel	34
	PMRL Grant and Monitoring Activities (1981-82)	
	Designated Scientific Authorities and Liaison Officers	44
	PMRL Project Leaders	48
	Representation on Technical Committees	50
PART E.	TECHNOLOGY EXCHANGE	55
	Industry	55
	Government Departments and Agencies	57
	Universities and Other Organizations	58
PART F.	PROFESSIONAL STAFF	61
	Metals Processing Laboratory	61
	Metal Development Laboratory	62
	Staff Changes	63
	Current Status	64
	PMRL Organizational Charts	64

PART A. MINERALS RESEARCH PROGRAM

PROJECTS

360002 - CORROSION OF STEELS IN SOILS
Project Leader - G.J. Biefer

A survey of metallic corrosion problems in Canadian soils, commissioned by CANMET, emphasized that underground corrosion failures of municipal water piping in Canadian cities are reaching epidemic proportions. The problem is national in scope and of considerable financial consequence. However, the scanty literature available does not specify the failure mechanisms involved.

A contract has been let to study the water pipe problem in the city of Calgary, as an example of municipal experience, where about 1000 failures occur every year. An interpretive history of past failures is being prepared, based on city records of about 13,000 failures; representative freshly-failed pipes and their soil environments will be examined to determine the operative damage mechanisms. The results will be distributed to Canadian municipalities.

360011 - ABRASION RESISTANT CAST-ON COATINGS
Project Leader - R.K. Buhr

Testing has been completed on dragger shoe castings produced with an abrasion resistant layer of chromium carbide on the wearing surface, using the CANCOAT technique developed at PMRL. They were tested over a two month period on trawl doors, used to keep fishing nets on or close to the ocean bottom, and were compared to standard alloy steel shoes commonly used. The CANCOAT dragger shoes were made of ductile iron. In general, the coated shoes wore at about the same rate as the standard steel shoes. The coated shoes were found to be abraded at an angle, rather than parallel, to the 1/4 inch coated surface; evidently, most wear occurred in the relatively soft iron matrix rather than on the intended abrasion-resistant layer. It is believed this might explain the poorer than expected results.

Another series of field tests on bullring segments used in crushing coal just prior to firing in thermal plants will be undertaken in fiscal year 1982-83. Both steel and ductile iron segments have been cast with a CANCOAT abrasion-resistant layer and will be included in the test program.

360012 - ABRASION RESISTANT PLATE STEELS
Project Leader - R.F. Knight

An important cost consideration for the Canadian minerals industry is the abrasive wear that occurs in mining, processing, and transportation operations. Attempts to develop plate steels with improved abrasion resistance, weldability and toughness by means of controlled rolling and direct-quenching have continued with the production of experimental steels based on the composition of commercial CHT-360 steel. Chemical modifications include the addition of niobium and variation of the carbon content. Three EXP-360 steels, as well as four direct-quenched Mn-Mo-Nb steels, were tested under contract to compare their abrasion resistance with that of various commerical materials. These tests confirmed that for low alloy steels of this type, low-stress abrasion resistance depends solely on the hardness developed. Two of the experimental steels had abrasion resistance comparable to CHT 360. Two further EXP-360 steels have been produced and are currently being evaluated.

Under another contract, the potential demand for direct-quenched plate steels was surveyed; the

study concluded that plate for abrasion-resistant applications is a low-volume, specialty steel market that would not justify installation of direct-quenched facilities.

360021 - WELD MECHANICS
Project Leader - J.T. McGrath

Distortion and residual stresses from welding are present in welded engineering structures. Distortion control is a major cost to welding fabricators and often must be corrected by expensive machining. Knowledge of residual stresses in welded structures is essential to determine the potential service life when failure due to stress corrosion, fatigue and brittle fracture is possible.

In the initial phase of this project, a state-of-the-art survey, conducted under contract, recommended the finite element method as the only technique capable of predicting residual stresses and distortion. Commercial programs are available having the capability of incorporating non-linear behaviour in modelling the welding process leading to residual stress. The limitations to the use of these programs are a lack of data on non-linear material properties at elevated temperatures, the very high computing costs, and lack of accurate experimental data for confirmation of the technique.

Further work on this project will endeavour to apply the finite element technique to the prediction of residual stress levels in single pass welds, with the long term goal of application to multipass welds.

360022 - REPAIR AND RECLAMATION BY WELDING
Project Leader - J.T. McGrath

There is now a strong incentive to reclaim and repair failed or worn out industrial components, in face of increasing material and energy costs in making new parts. The development of welding procedures for repair and reclamation is difficult because of the wide range of metals and alloys encountered and the problems involved in determining inherent structural and mechanical property requirements in the field.

The first phase of this project was to conduct a survey under contract to determine the status of the field in Canada. The results of this survey indicated there is much work to be done in generating and assembling the required information for the use of welding technology for repair and reclamation. The development of a handbook was recommended.

360023 - HEAT AFFECTED ZONE TOUGHNESS
Project Leader - J.T. McGrath

The objective of this project is to develop microalloy plate steels with improved notch toughness in the heat affected zone (HAZ) of high heat input weldments. The primary application is in the seam weld of linepipe. The steels could also be used in marine and offshore structures.

The work has been done in co-operation with the Canadian steel industry. Identification of microstructural constituents was contracted out in part to Canadian universities.

It had been previously established that the addition of titanium at the level of 0.01 per cent with a Ti/N ratio of less than two, can provide a reduction in grain size in the course-grained HAZ by a factor of two while improving the notch toughness by as much as a factor of three. The work in FY 1981-82 was concerned with the following, (1) preparation and evaluation of commercial heats containing Ti and N additions, (2) identification of the kinetics of titanium-rich precipitate formation, (3) assessment of the microstructure of the as-rolled titanium-nitrogen steels, (4) evaluation of the effect of solidification rate on the distribution of titanium rich precipitates in slab cast steels, (5) determination of the effect of composition variation (Nb, V, Mo) on the structure and properties of titanium-nitrogen steels.

Results have shown that grade 483 pipe, prepared with titanium and nitrogen additions, had an improvement in HAZ notch toughness comparable to experimental laboratory heats.

Analysis of the precipitate particles by the dedicated STEM microscope at McMaster University indicated that metastable niobium-titanium nitrides formed in the as-cast steel. These particles are replaced by titanium-rich niobium carbonitrides during reheating, rolling and weld reheating operations.

Microstructures at five different stages of thermomechanical processing were examined and the results indicated that the titanium-nitrogen steel had a smaller and more uniform grain size than the base steel in the as-rolled condition.

The rate of solidification of the as-cast titanium-nitrogen steels had no significant effect on the precipitate particle size distribution. Investigation continues on the role of Nb, V, and Mo on the structure and properties of titanium-nitrogen steels.

360031 - CHARACTERIZATION OF WELD DEFECTS
Project Leader - O. Vosikovsky

Failure-free operation of a pipeline depends on pre- and in-service inspections and defect acceptance criteria. Initial defects introduced during fabrication, particularly by welding, can grow during service, and result in failures if not detected by inspection. One of the mechanisms which causes the growth of defects in crude oil pipelines is corrosion fatigue. Hydrogen sulphide present in sour crude oil substantially accelerates the growth of the defects.

The objective of this project is to determine the fatigue life of a pipeline with a defect of known size or, alternatively, the allowable size of a defect that would not cause failure during the expected life. The project has been a co-operative venture with Interprovincial Pipeline Ltd., The Welding Institute of Canada and Techno Scientific Inc. The original impetus was given by the National Energy Board.

A computer program was developed for calculating the corrosion fatigue life of a pipeline, based on integration of fatigue crack growth rate curves over the characteristic spectrum of pressure fluctuations in a pipeline. The fatigue crack growth rates in crude oil containing various concentrations of hydrogen sulphide was determined on laboratory specimens for several configurations of initial defects. The characteristic pressure spectrum was synthesized from actual operating records of an oil pipeline.

The predicted fatigue life was verified by testing full size (863 mm diam) pipes with defects of various sizes, pressurized with crude oil containing 100 ppm of hydrogen sulphide using the characteristic pressure spectrum.

The final results are given in terms of allowable defect depths in a particular transmission pipeline for varied hydrogen sulphide contents in crude oil and several expected lives. The computer program can be easily used for determination of allowable defect sizes in other pipelines provided that a characteristic pressure spectrum is available.

360041 - PLASTIC FLOW, FRACTURE, AND STRESS ANALYSIS
Project Leader - W.R. Tyson

The objective of this project is to evaluate and further develop test methods which measure the fracture resistance of ductile materials, and experimental and analytical methods which estimate residual stress levels. During the past year, results of instrumented impact tests have been compared with measurements of nil-ductility temperatures of ship plate. An extensive review of state-of-the-art methods of residual stress measurement has been written, and experimental work is under way to use the hole-drilling technique to measure variations of residual stress with depth.

360042 - PORTABLE X-RAY STRESS DIFFRACTOMETER

Project Leader - D.W.G. White

It is important for many purposes to be able to measure the stresses in engineering structures, such as for calculation of permissible loads, determination of inspection intervals, product acceptance, assurance of public safety, design evaluation and service life prediction.

Although stresses can be determined using strain gauges, it is usually unacceptable to measure stresses applied in service in this way, since material must be removed by drilling or some other means from the location in the structure at which the stress is determined. On the other hand, both residual and applied stresses can be measured non-destructively in the surface of a structure by an X-ray diffraction technique. Generally, stresses have not been measured in the field by X-ray diffraction, because the equipment has not been mobile.

Through contracts with industry, PMRL/CANMET is currently attempting to develop a portable X-ray stress diffractometer that will measure stresses accurately and quickly in a routine manner. The Department of National Defence has contributed substantially to the contract funding.

Although there were delays during the past year in identifying suitable contractors and negotiating contracts, significant progress was made. A source was found for more compact position sensitive detectors, permitting improved diffractometer geometry; a contract to supply a pair was negotiated. The position sensitive detectors are located on both sides of the X-ray tube in the head of the instrument, and simultaneously measure shifts in X-ray lines corresponding to lattice strains in two directions in the material. The signals from the detectors are processed in real time on a micro-computer system to give an immediate surface stress measurement.

With the prospect of more suitable detectors, the decision was taken to abandon an existing set of drawings for a head that would have been scarcely transportable and to design a truly portable instrument. Drawings for the redesign were delivered before the end of FY 1981-82.

With development of the equipment well in hand, a survey of the instrument's potential marketability was carried out. It was predicted that 25 units could be sold in North America at about $100,000 each in the first year, and then about 80 units per annum for the next three or four years.

360051 - MICROSTRUCTURAL EFFECTS ON STRENGTH AND TOUGHNESS IN ENGINEERING ALLOYS

Project Leader - J.D. Boyd

This project was begun in FY 1981-82 to explore the basic relationships between microstructure and the mechanisms of yielding and fracture in various engineering alloys. Current work is concentrated on the microstructure and fracture behaviour of controlled rolled microalloyed steels. The prior austenite grain size, lath-packet size, and type of carbon rich phases (carbides or MA) are being varied systematically by conventional heat treatment and Gleeble weld simulation. Toughness is being evaluated by standard Charpy tests, and the microscopic origins of fracture identified by means of low-blow Charpy tests. In addition, the transformation kinetics of deformed austenite are being studied by dilatometry and metallography.

360052 - DEVELOPMENT OF NON-LEADED, FREE MACHINING STEEL

Project Leader - D.E. Parsons

Phase I of this project was completed on July 31, 1981; it involved a critical review of the mechanics of machining, the role of inclusions, modern developments necessary to remain competitive, and recommendations concerning research options.

After consultation with Canadian steel manufacturers it was decided that Phase II of this research should involve a detailed study of the effect of eliminating Al_2O_3 inclusions by com-

parison of Al- and Ca-deoxidization practice on strand-cast 1146 free-machining steel. The object of the project, elimination of lead additions, will be attained by shape-control of the sulphide and Ca-type anorthitic inclusions. High-speed machining tests will be made with carbide tools; and slow speed tests with high-speed steel tools. Research would then be extended to elimination of lead in the 12L14 leaded steels.

A midterm Phase II progress report has been submitted, indicating satisfactory progress in preparation of a commercial heat for determination of machinability and metallographic parameters. The Phase II research on 1146 steel will be completed by July 31, 1982.

370002 - TECHNOLOGY FOR THE METAL CASTING INDUSTRY
Project Leader - R.K. Buhr

INTERCRITICAL HEAT TREATMENT

Investigations continue on the heat treatment technique to improve the low temperature properties of plain carbon and low alloy steel castings. Following cooling from the austenitizing temperature, castings are reheated to a temperature within the critical range (e.g., between the AC1 and AC3 temperatures) and either quenched or air cooled. The castings are then given the normal tempering treatment.

Tests on LCC cast steel show the transition temperature was lowered by up to 35°C when the steel was quenched and up to 15°C following air cooling. Work is now underway on an LC2 low alloy steel.

The intercritical/quench heat treatment results in a microstructure characterized by fine lamellae of ferrite and martensite, whereas the intercritical/normalize treatment refines the grain size. The heat treatment is used to either salvage castings failing to meet low temperture specifications or to meet more stringent specifications without increasing the alloy content of the steel.

FILTERS FOR FERROUS AND NON-FERROUS CASTING

Tests have been carried out to evaluate ceramic foam filters for casting aluminum, magnesium and copper-base alloys. Although effective in removing dross and certain indigenous-type inclusions, these commercial filters broke down on occasion to create other defects in the castings. Some success was achieved in coating steel wool filters to prevent iron pick-up in aluminum melts.

The ceramic foam filters could not withstand the high pouring temperatures needed for ferrous alloys; however, a technique has been developed to filter grey and ductile irons and its effectiveness is being evaluated using a special dual-casting design. Work has also been undertaken to improve bonding techniques to hold the refractory particles of the filter material together to simplify the handling and placement of the filter in the gating system. Industrial trials of this filter should be underway next fiscal year.

OPTIMUM PROPERTIES IN MAGNESIUM ALLOY SAND-CASTINGS

The increased use of magnesium alloy castings in aircraft has called for stringent adherence to specifications to ensure that the properties required are obtained in specific areas of the casting. Separately cast test bars do not necessarily reflect the properties of the casting itself. Superior properties in the casting are achieved by proper manipulation of chilling and feeding in highly stressed areas. This research was directed towards determining the properties of magnesium alloy test pieces taken from critical areas of an actual casting.

A report has been written listing the various properties measured on a variety of commercially available magnesium alloys and certain experimental alloys developed in these laboratories.

CAST-IN-PLACE COPPER TUBING IN COPPER TUYÈRES

directly in a copper tuyère casting have been determined and a report was written on the procedure. This technology assists Canadian non-ferrous foundries in the production of a new design of tuyère for the Canadian steel industry which is more efficient and reliable. It is hoped this will also assist in greater use of domestically produced tuyères.

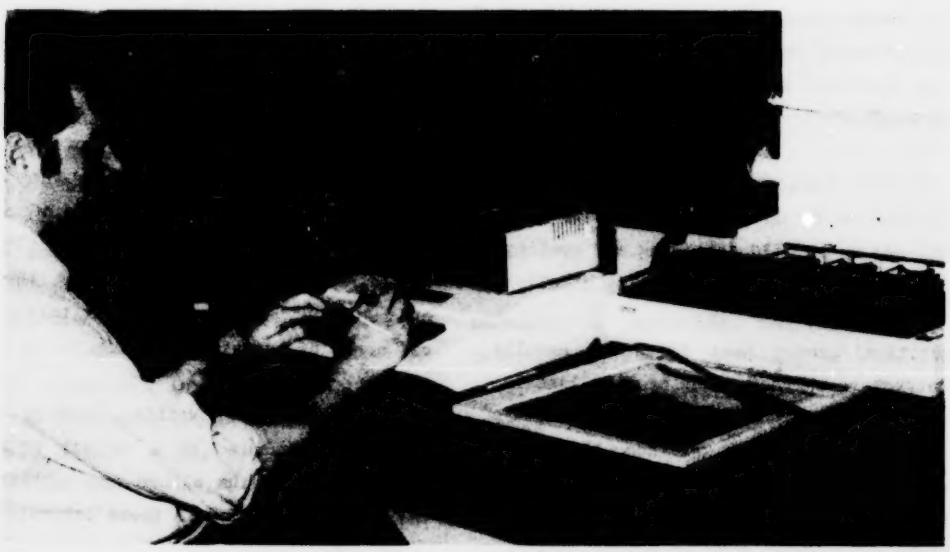
Some additional work has been performed on reducing or eliminating porosity in the wall section of these tuyères to further improve their quality.

CUPOLA MELTING EFFICIENCY SURVEY

Iron foundries using cupola furnaces as primary melting devices constitute a significant segment of the Canadian foundry industry. In 1981 cupolas in 78 foundries across Canada consumed $35 million worth of imported coke while producing iron castings worth approximately $0.9 billion. In FY 1981-82 the goal of the cupola survey was to transfer to the foundry industry the technical and practical knowledge acquired by CANMET personnel during the first stage of the survey. The application of this knowledge by Canadian cupola operators should lead to an industry-wide reduction in coke consumption of 3-5% which would reduce expenditure on imported coke by at least $1 million.

The primary method of transferring technology in this FY has been the regional workshop. However, other activities have also played significant roles in ensuring the effectiveness of the process. A census of cupola operation in Canada was conducted by telephone. In addition to providing accurate information on the number of cupola foundries and the productivities of each foundry, the census resulted in the establishment of valuable personal contacts at each foundry and the creation of an up-to-date, computerized mailing list.

A major advance in foundry technology transfer has been achieved by the development at PMRL of a series of four micro-computer programs which greatly facilitates the analysis and control of cupola operations. In anticipation of the development of software aimed at other foundry opera-



D.L. Whiting of the Foundry Section writing a micro-computer program to be used by foundrymen for analyzing cupola operations.

tions, the cupola-oriented software has been identified as the "Cupola Series" of "CANMET Foundry Software". The cupola software has been used at PMRL to ensure rapid and accurate responses to numerous requests for assistance and in the regional workshops for teaching and demonstrations; it will be subjected to intensive industrial trials early in FY 1982-83, prior to being offered commercially to the industry.

Based on information obtained from both the efficiency survey and the foundry census, four regional workshops were planned for Edmonton, Alberta; Cambridge, Ontario; Trois Rivières, Québec and Moncton, New Brunswick. Response to the workshops was far greater than anticipated, and two additional workshops were held, a second in Cambridge, and one in Hamilton, Ontario. A second workshop in Québec may be held at Trois Rivières in early FY 1982-83.

Over 160 persons representing approximately two-thirds of the cupola foundries attended the workshops. They received 6 hours of lectures based on a CANMET cupola handbook and two hours of "hands-on" microcomputer demonstrations. In addition they were exposed to a comprehensive literature display which included numerous CANMET foundry reports as well as several hundred cupola-related articles from international foundry journals. Industry evaluation of the workshops was highly favourable and there were numerous requests for future surveys and workshops on all aspects of foundry operations.

GREY AND DUCTILE IRON WORKSHOP

A workshop on grey and ductile iron was organized and presented at PMRL by members of the foundry section and three speakers from industry. The response was such that two workshop sessions had to be held; a total of 65 people attended. Topics included structure and properties of grey and ductile iron, innoculation techniques, cupola and electric melting practice, foundry sand, quality control, risering, high alloy cast irons, ductile irons and new technology.

370003 - DEGRADABLE SAND AND CORE BINDERS
Project Leader - R.K. Buhr

The initial feasibility studies in industry of the newly developed binder system for sand mould and core production were successful and prompted negotiation to find a contractor to more fully investigate commercialization of the process. In addition patent applications were filled and PILP funding was obtained for the additional development costs. Pfizer Canada Ltd. indicated interest in the process and are formulating a comprehensive work plan to fully test it in commercial foundries. It is hoped this next stage will start early in the next fiscal year.

Some additional work has been performed on other binders within the same generic group of chemical compounds and with certain other additives that make the binders less susceptible to variations in relative humidity.

370004 - CONTINUOUS CASTING OF METALS
Project Leader - R.K. Buhr

The Ontario Research Foundation was awarded a contract to design, construct and calibrate an apparatus to measure the frictional characteristics of mould fluxes used in the continuous casting of steel. The apparatus was designed and constructed but not calibrated. The contract was terminated but the apparatus was left at ORF because of indicated industrial interest in its use. It is hoped ORF will undertake completion and calibration of the apparatus for operation at elevated temperatures.

370005 - PERMANENT MOULD CASTING
Project Leader - R.K. Buhr

INOCULATION OF IRON CASTINGS MADE IN PERMANENT MOULDS

A gravity permanent mould casting machine has been designed and constructed. A die design for this machine has also been completed and both cast-to-size and machined dies have been produced in grey

cast iron. Special thermocouple holes have also been machined to permit a continuous record of the thermal cycles encountered in the die. In addition, a test mould for a bar of 25 mm diam. has been produced and preliminary tests performed to obtain information on pouring temperatures and die castings that can be used on the larger test dies.

CAST-TO-SHAPE DIES FOR PERMANENT MOULDS

Techniques have been developed to produce permanent mould dies that have a cast-to-shape die cavity. The Shaw Process is used for the working faces of the die, which produces a surface requiring a minimum of preparation prior to placing the die in service.

TESTING OF DIE MATERIALS AND DIE CASTINGS

Problems have been encountered in obtaining a satisfactory apparatus design for combined testing of die materials and die coatings. A dip-type test would be used in which the candidate material is regularly immersed and withdrawn from a bath of molten metal, with subsequent ejection of the solidified shell. Difficulties have been encountered in consistently producing a solidified shell on the die in this type of test; therefore it may be limited to testing thermal fatigue properties of the die materials.

For higher melting point metals, there would be considerable problems with maintaining bath conditions constant for long periods of time and so this test may be applicable only for low melting point metals. An alternate technique using inductive heating of the test die material is being investigated.

DESIGN AND EVALUATION OF LOW PRESSURE PERMANENT MOULD TEST CASTINGS

Most of the work has been performed on a relatively simple dish-shaped casting. A fairly comprehensive program was undertaken to better understand the operation of the low pressure casting machine and the effects of the numerous parameters on the quality of the casting produced. Variables such as die coating thickness, melt temperature, die temperature, fill time, fill pressure, stock-neck temperature, etc. have been investigated and correlations made with casting quality.

Based on this work, design of a more complex casting will be made and evaluated in the next fiscal year.

MATHEMATICAL MODELLING OF HEAT FLOW IN PERMANENT MOULDS

A contract for this work was given to Ottawa University. The first phase of this contract has been completed. A preliminary mathematical model has been developed to permit heat flow calculations to be made in a two-dimensional die for cast iron. The next phase of this work will be to model heat flow in three-dimensional dies of a more complex shape.

370006 - ELECTROSLAG CASTING
Project Leader - R.K. Buhr

Unforseen delays in the site preparation have delayed this project. To date, electroslag casting equipment using a single electrode has been built and is operational. Water-cooled aluminum moulds have been produced in the PMRL foundry with the water-cooling channels cast in place using the recently developed sand binder system. This technique should reduce the mould costs significantly.

In addition, a contract was placed with Davis Engineering Ltd. to design the servomechanism required for the production of thin-wall electroslag castings. This has been completed and the necessary equipment purchased. The construction of the apparatus will be started in the next fiscal year with operation planned for the fall of 1982.

370008 - CANMET FOUNDRY NEWSLETTER
Project Leader - R.K. Buhr

The Canadian foundry industry is kept informed on research underway at the Physical Metallurgy Research Laboratories through periodic issues of the CANMET Foundry Newsletter. This continues to be a very useful vehicle for the transfer of technology judging from the response of the industry.

370011 - OPTIMIZATION OF ROLLING MILL PERFORMANCE
Project Leader - A.F. Crawley

The demand for higher strength plate and strip steels for pipeline, transportation and structural applications has created competitive development of new steel grades. These steels require increasingly greater mill power for rolling relative to standard schedules for plain carbon steels and an increasing sophistication of schedule design in order to match deformation sequences with metallurgical changes in the steel.

A major undertaking was to design a system to control roll screwdown, direction and speed operations automatically by microcomputer. This control system will significantly increase our capability in developing production-efficient rolling schedules in the laboratory. The microcomputer used to acquire mill performance data was upgraded recently to increase computer speed and memory and circuit boards for process control were installed. Computer programs were written for initial testing of key hardware and software elements. A system of relay switches was designed to replace the manual control system for automatic operation for the mill side of the interface design .

A feasibility study was conducted to recommend a system capable of increasing the speed of the current mill gap adjustment system. The final recommendation suggested the replacement of the existing screwdown motor with a top speed of 700 rpm by a new motor having a top speed of 1800 rpm with position indication and regulation.

The second CANMET Rolling Mill Technology Seminar was held on May 27-28, 1981. About 90 representatives of industry, government and universities from Canada and the United States attended the program of invited papers. Sessions dealt with modelling, sensing and shape control in the rolling process, metallurgical aspects of controlled rolling, and metallurgical requirements for plate and strip products. The seminar succeeded in its purpose to promote interaction between industrial and research efforts to advance rolling mill technology in Canada.

A three year contract was awarded to McGill University to determine the causes and examine techniques to minimize the undesirable duplex grain structure which develops during controlled rolling of micro-alloyed high strength steels. Research in the initial phase has determined conditions under which grain coarsening and grain refinement occur during austenite deformation at high temperatures.

370012 - INFLUENCE OF MICROSTRUCTURE ON FORMABILITY
Project Leader - A.F. Crawley

The formability of sheet materials is dictated not only by intrinsic flow characteristics but also by microstructural features and irregularities. A fundamental study of microstructural features, including texture and internal stresses associated with phases, will yield basic scientific data for interpretation of forming problems.

Tooling and instrumentation were installed and tested for Limiting Dome Height (LDH), hole expansion and stretch bend testing. Existing computer programs for data collection and processing by tensile testing were extended to calculate and plot parameters which quantitatively describe the strain hardening behaviour of sheet metals.

370014 - FLUIDIZED BED COOLING
Project Leader - A.F. Crawley

The use of fluidized beds for in-line heat treatment of small sections such as patenting of wire

is a well established technology. Application to the processing of bulk shapes such as rails and rods has been proposed but experimentation has been very limited. The demand, however, for improved properties in shaped products has created a new interest in fluidized beds as a technique for controlled cooling and transformation.

The fluidized bed designed and constructed at CANMET has been applied in two modes of operation. In the first, plates and rods of steel were immersed in a bed at ambient temperature to increase the cooling rate through the transformation temperature range to give increased strength. The resultant properties were sensitive to the orientation of the part in the bed because of the effect on directional air flow and consequently on heat transfer rate. In the second, quasi-isothermal transformation was induced in suitable alloy steels using the bed at high temperatures in the range 450-575°C. Besides achieving superior microstructures and strengths, this mode of operation was not sensitive to the orientation of the plate.

The first phase of a PILP contract awarded to Algoma Steel Corporation, to examine the feasibility of on-line processing of shaped steel products using fluidized beds, was completed. The study concluded that fluidized bed systems are technically and economically feasible for industrial processing of alloy steel shapes and for soaking pit operations for carbon-manganese steels.

370021 - HEAT TREATED RAIL
Project Leader - D.W.G. White

The increasing use of unit trains for commodity transportation - minerals, coal, grain and the like - coupled with the high axle loadings characteristic of North American practice, have led to unacceptable rates of rail wear, particularly on tight curves in sections of track carrying high traffic densities. Questions of safety apart, track maintenance is expensive and seriously disrupts traffic on busy lines.

The response of the rail producers to this situation is to make a premium rail that is harder and has a longer life than standard rail. Progress has been made in Canada and elsewhere; however, it is acknowledged that an optimum premium rail has yet to be developed. Since its inception, the purpose of research on rail in PMRL/CANMET has been to provide support to Canada's two rail producers in their quest for a better premium rail.

Early work in the project focused on evaluating a spectrum of rail steel compositions transforming to the microstructure and hardness representative of the best of the current generation of premium rail. Two separate approaches were adopted. In the first, steel chemistries were selected which resulted in the desirable structure and hardness on cooling at rates characteristic of rails on the hot bed of a rolling mill. In the second approach, lean alloy steels were transformed to similar hardnesses and microstructures at mildly accelerated cooling rates which could be reproduced on the hot bed of a rail mill with minimal capital expenditure. This work is complete.

Current rail research is different in objective and methodology. The objective is to assess the

Mrs. V. Moore of the Engineering and Metal Physics Section is analyzing inclusions in a sample of rail steel using an electron microprobe analyzer.

feasibility of producing a rail with a desirable microstructure that is incrementally harder than current premium rail (Rc44 vs. Rc38). Specimens representative of rail are transformed in a quasi-isothermal manner at elevated temperatures in a fluidized bed. Research is focused on evaluating the properties of those steels which transform to a desirable microstructure at the target hardness.

THERMAL PROCESSING

During the past year, progress has been made in determining the optimum operating conditions of a fluidized bed to produce a desirable microstructure of high hardness (>Rc42) in plate samples rolled to thicknesses simulating rail heads. This work has been of considerable interest to one of Canada's rail producers currently planning a new shapes (rail) mill and who is contemplating installing a fluidized bed for heat treating rail.

WEAR

Work has also continued on evaluating the wear resistance of commercial and experimental premium rail steels. This is a collaborative venture with the NRC Tribology Laboratory in Vancouver who have devised and constructed a rig which imposes scaled forces on wear specimens in the form of a pair of rotating discs, one machined with the profile of a wheel, the other with the profile of a rail. Disc pairs for testing have been heat treated at PMRL/CANMET to give three different microstructures at each of three hardness levels (i.e. a matrix of nine). The microstructures of these specimens are characterized by optical and transmission electron microscopy, the transmission electron microscopy being carried out on contract at the Technical University of Nova Scotia.

370031 - AUTOMOTIVE MATERIALS

Project Leader - A.F. Crawley

Sheet steels for automobiles are in a continuing state of development dominated by two unrelated trends; first, to replace hot rolled sheet with cold rolled sheet in standard and high strength grades and second, to install continuous annealing lines for processing cold rolled sheet. This is especially evident in the United States. These lines have been shown to produce carbon steel sheet with improved ductility. The continuous process is also superior to batch processes to produce high strength steels, which are predicted to be in increasing demand by the automobile manufacturers in the future. Work has concentrated on certain aspects of transformation-strengthened (dual-phase) steels: the effects of a galvanizing thermal cycle on properties of continuous annealed dual-phase steels, conclusion of research into the feasibility of producing dual-phase steels by batch annealing and development of a micromechanical model to further understanding of these steels.

Cold rolled dual-phase steels were subjected to two processing cycles to simulate the thermal history of the base metal during hot dip galvanizing. First, five commercial steels and one laboratory steel were heated to 460°C by immersion in a fluidized sand bed and held for 5, 10 and 20 seconds. The effects on tensile properties were characterized by an increase in yield strength, return of yield point elongation and a decrease in tensile strength. Microstructural examination showed that the property degradation was accompanied by a breakdown of the martensitic phase to bainite. The degree of property change was dependent on composition and molybdenum bearing steels were least sensitive to the thermal cycle.

Second, a thermal cycle was applied to a molybdenum and a vanadium bearing laboratory steel to simulate in-line galvanizing during cooling after intercritical annealing. In this case steels were intercritically annealed but cooling was interrupted by holds of 5, 10 and 20 seconds at 460°C. The effects on properties were similar in form although not in degree to the reheat cycle. The underlying process, however, is different because the hold temperature is above the M_s temperature. Property losses were significantly less for the molybdenum bearing steel than for the vanadium-bearing steel. The results, however, strongly

indicate that dual-phase steels of appropriate composition can be galvanized in-line using short dip cycles, similar to a Sendzimir line process, without appreciable losses in properties.

Earlier work on C-Mn steel development to produce dual-phase steels by batch annealing was extended to other compositions containing chromium and nickel. Although some compositions showed characteristic dual-phase properties, the strength-ductility relationship, as for C-Mn steels, was inferior to that of continuously annealed steel.

Work has been completed on the testing and modeling of a batch-annealed C-Mn steel. Three aspects of importance emerged: (1) Modelling of the dual-phase flow curve was done by assuming an "elastic" model with no plastic relaxation of stress gradients, and alternately, by assuming a "fibre loading" model with complete relaxation. These models respectively gave upper and lower bounds, to the flow stress. (2) The grain size dependence of the yield stress of ferrite and composite flow stress behaviour was determined. The grain size effect persists to large strains. (3) The kinetics of partitioning of manganese during intercritical annealing was studied in collaboration with scientists at McMaster University. Results showed that even after 100 hours at 695°C partitioning is only 80% complete and that manganese diffusion in austenite controls the process.

In another area of automotive materials, a contract was awarded to McMaster University to study the microstructural features which limit formability in mass produced cold forgings such as wrist pins and fasteners. The ultimate objective of this work is to separate the effects of microstructural features, such as inclusions, from the intrinsic material flow behaviour in order to produce the cold formed products from higher strength steel grades.

370041 - MARINE MATERIALS

Project Leader - J.B. Gilmour

Work on this project is aimed primarily at providing the necessary information on materials to enable the construction of vessels which can operate successfully year round in Canadian Arctic waters. Proposals to develop the petroleum resources of the Beaufort Sea and the gas resources of Melville Island both involve the construction of icebreaking ships to transport these resources to southern Canada. To assist in defining the research needed to aid in the selection of steels for these vessels, discussions were held with representatives of the companies involved, a Canadian steel producer and the Canadian Coast Guard.

Work continued in the laboratory on the evaluation of samples of hull plate supplied by the Coast Guard, from ships operating in the Arctic, and a summary report was prepared. Although fracture resistant steels are readily available it is apparent that most commerical ships are being constructed from steel that is not required to be impact tested, and all too frequently has an impact energy of less than 15 J in a standard Charpy V-notch impact test at 0°C. As part of this evaluation of steels a four metre long crack in a 10 month old Canadian ship was investigated in some detail. In this particular failure the cracking originated at the toe of a rather poor weld attaching the bilge keel to the hull. The source plate had less than 15 J impact energy at 0°C, the approximate temperature of the water when the cracking occurred. The crack stopped in manual welds which were found to have very good fracture properties, although it is believed that the stress in the plates near these welds was relatively low and contributed to the crack arrest.

Initial work was done on the welding of fracture tough steels using a high energy input one-sided submerged arc process. This research will determine if adequate toughness can be obtained in the weld and HAZ with this high productivity process.

A review of the various specifications for fracture tough steels for possible use in arctic icebreaking vessels was carried out, with emphasis on the suitability of CSA grades of steel for this application. It appears that CSA G40.21 Grades 260 WT, 350 WT and 350 AT in the normalized condition should have properties at least equal to those required for steels produced to international ship steel standards. Research to determine the properties of these grades in the as-rolled, normalized and, where possible, control-rolled condition, has been proposed.

Work continued on the corrosion of welds in icebreaking ships with the completion of an apparatus, patterned after one in use in Finland, to study this phenomenon. Samples of three grades of hull steel were obtained, specimens machined and preparations were made to test various combinations of welding electrode and hull steel.

Four test racks of corrosion specimens, each containing 21 alloys, were placed in Barrow Strait south of Resolute by the Department of Fisheries and Oceans early in April of 1981. At the time of preparation of this report (May 82), only one of the racks had been recovered, although DFO remained optimistic that two more will eventually be recovered. One rack of corrosion specimens was prepared for the Arctic Research Establishment at Pond Inlet for placement during January 1982 in Eclipse Sound for 6 months exposure.

370042 - HIGH-STRENGTH COPPER BASE ALLOYS FOR SHIPBOARD SYSTEMS

Project Leader - M. Sahoo

Although research and development work on this project has been done with financial support from the Department of National Defence (DND), the work is also of interest to the Canadian Coast Guard Service (CCGS), Canadian Stone Marine Ltd., and other Canadian brass and bronze foundries.

During FY 1981-82, transfer of technology on Cu-Ni casting alloys was completed and work on the dealuminification of cast, and cast and welded, Ni-Al bronze alloys was also finished.

CCGS icebreaker propellers, cast in Mn-Ni-Al bronze, tend to have low fracture toughness. After discussion with both DND and CCGS, a project was initiated to identify the mechanisms responsible for the low fracture toughness of the sand-cast propellers and to recommend industrially usable heat treatments to improve their impact properties. Canadian Stone Marine Ltd. has been involved in the project by assisting in the measurement of cooling rates of propellers.

CUPRO-NICKEL CASTING ALLOYS

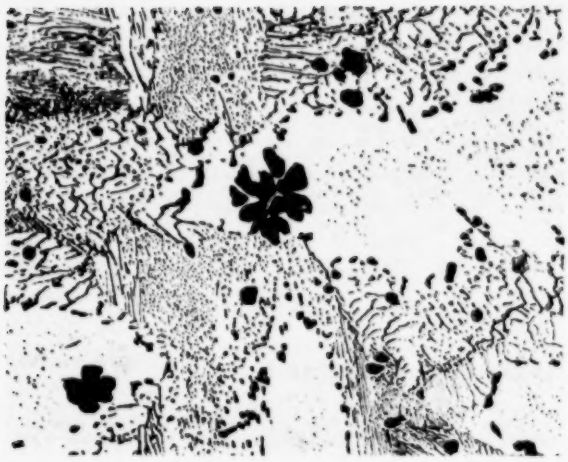
As part of a PMRL/CANMET program to develop Canadian capability in the production of high quality admiralty castings, a 318 kg six-valve chest with certain auxiliary components was cast in a Southern Ontario bronze foundry in niobium-modified 70/30 Cu-Ni alloy. Production of the casting to DND specifications was financed by DND. The radiographically sound casting passed the 2758 kPa water pressure test and was shipped to Montreal in the fully machined condition for shock testing. This hull-valve casting will replace an existing imported casting in a Canadian submarine.

NICKEL-ALUMINUM BRONZES

Weldability studies of Ni-Al bronze casting alloys have been completed and the importance of a corrosion-inhibiting heat treatment on welded specimens has been demonstrated. Welded and post-weld heat treated specimens have been supplied to the Dockyard Lab, Defence Research Establishment Atlantic for corrosion studies.

Microstructure and mechanical properties of Ni-Al bronze alloys cooled at very slow rates, characteristic of heavy section sand castings, have been determined and compared with those of test bars from sand-cast keel blocks.

Since Ni-Al bronze alloys are also used for casting ship and submarine propellers, work is underway to study their corrosion fatigue behaviour in sea water. To this end, fatigue-crack growth rates in standard laboratory specimens are being determined in air and salt water for both as-cast



Microstructure (500X) of a nickel-aluminum bronze alloy propeller, showing iron- and nickel-rich kappa phases in an alpha matrix.

and cast and heat treated (700°C, 6 h, air cool) conditions.

PROPELLERS FOR ICE BREAKERS

To examine the effect of composition on the microstructure, tensile and impact properties of Mn-Ni-Al bronze alloys, a number of rods and square bars of different manganese and aluminum contents have been cast. Microstructure and mechanical properties of the alloys have been studied in both cast and, cast and heat treated (stress-relief heat treatment), conditions. The cast rods are being heat treated to simulate microstructures representative of heavy sections in sand castings, such as found in ice-breaker propellers.

380012 - DEVELOPMENT OF INSTRUMENTATION AND TECHNIQUES

Project Leader - R.H. Packwood

As part of a program to replace obsolete electron optical equipment in PMRL, a CAMECA MBX microprobe was installed and commissioned in FY 1981-82 to replace a 1965 model. This instrument has superior electron optics which will permit accurate analysis of areas of the order of one square micrometre for acceptably low counting times. A spectrometer equipped with a large lead stearate crystal permits analyses of elements down to boron. The microprobe is also equipped with an X-ray energy dispersive analysis system and with a PDP-11 microprocessor to handle data and control the spectrometers.

Modern equipment for analysis of hydrogen will be installed early in FY 1982-83, replacing an old glass vacuum system using mercury, now judged to be a safety hazard. The analysis group is working on a method for hydrogen analysis which would distinguish between absorbed (molecular) and combined (atomic) species, based on incomplete Russian work. The sample is anodically dissolved in the presence of a known quantity of an organic free radical which reacts with atomic hydrogen. The quantity of the radical that is neutralized is subsequently determined. Molecular hydrogen would be determined in a second step, probably involving a catalytic reduction.

380021 - CERTIFICATION OF NDT PERSONNEL

Project Leader - V.L. Caron

Since 1960, PMRL has been authorized to certify NDT personnel to Canadian Government Specifications Board standards by administering a system of practical and written examinations through a network of test centres set up across Canada. PMRL's main responsibility is to determine eligibility of applicants and to design, set and mark examinations, supply test samples, maintain records and issue certificates. The program operates on a cost-recovery basis.

During FY 1981-82, apart from ongoing activities, the main objective was to continue to implement a three-level system. New standards in radiography and ultrasonics have been put into effect for three levels and certification was started in eddy currents for Levels I and II.

During the year more than 750 certificates were issued in the various nondestructive testing methods. Two courses on industrial radiography were given to DND personnel on a full cost-recovery basis.

PART B. ENERGY RESEARCH PROGRAM

PROJECTS

420501 - MATERIALS FOR TAR SANDS PROCESSING
Project Leader - A.W. Lui

Tar sands processing involves handling and transport of large quantities of abrasive raw material and waste. This creates an ongoing problem of equipment wear due to abrasion and corrosion processes induced by the presence of water and air. To minimize the overall wear, the use of suitable wear resistant materials is required. Some guidance into the selection of materials for sand-water slurries is forthcoming from laboratory tests which show that at high velocities of transport the use of abrasion resistant steels might be beneficial when corrosion rates are low. On the other hand, when corrosion largely contributes to the overall wear, as in turbulent tailings slurries, the use of corrosion resistant materials will be preferable. The final choice will depend on economic evaluation of initial capital costs of construction versus extended life benefits through lower operating costs.

420502 - PRESSURE VESSELS
Project Leader - J.T. McGrath

Future processing plants for the treatment of tar sands and heavy oil, for coal liquefaction and gasification, will require pressure vessels of increasing size and service capability. The objectives of this project are to develop and evaluate fabrication and inspection technologies for pressure vessels, and to characterize the in-service property requirements of pressure vessel materials.

WELDING PROCESSES

The following studies commenced under contract in the FY 1981-82.

(a) Development of a flux cored narrow gap system for welding heavy section 2.25 Cr-1 Mo steel.
(b) The application of electroslag-forming technology to the fabrication of pressure vessel nozzles.
(c) Hydrogen cracking in 2.25 Cr-1 Mo weld metal.

In-house activities were concerned with the preparation of weld overlays of 309, 316L, and 347 stainless steel on 2.25 Cr-1 Mo steel for the evaluation of hydrogen embrittlement and disbonding in the overlay.

NONDESTRUCTIVE EVALUATION

Two studies dealing with the location and sizing of welding defects in heavy section welds are being done under contract. A multitransducer ultrasonic system was assembled and the feasibility of the system for locating and sizing of defects of varying size and orientation was established. Further experimental work on sizing of defects is anticipated.

In the other NDE study acoustic emission is being used to monitor heavy section welding and detect the formation of defects during welding. The system is based upon the use of advanced pattern recognition and signal classification techniques to provide real-time process and quality control.

PROPERTIES OF PRESSURE-VESSEL MATERIALS

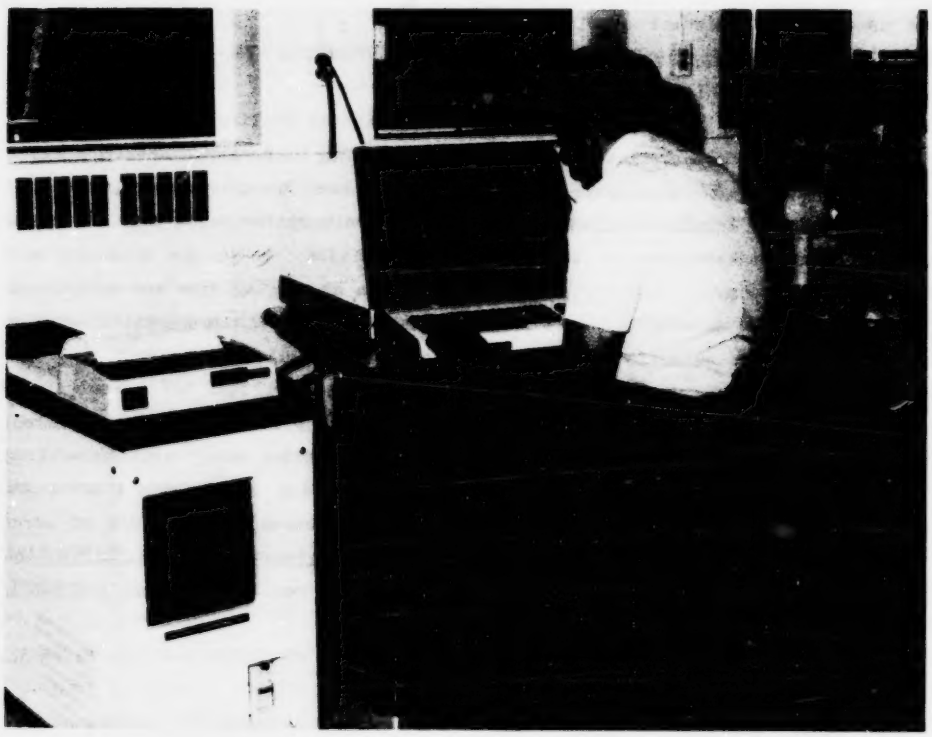
The microstructure and mechanical properties of 2.25 Cr-1 Mo base metal and weld metal and stainless steel weld overlays, were examined in the as-fabricated condition and after simulating various in-service environments.

An acceptable level of notch toughness was achieved in 2.25 Cr-1 Mo weld metal only after post-weld heat treatment. Rare earth additions to 2.25 Cr-1 Mo base metal improved the resistance to temper embrittlement. However, the rare earth treatment slightly reduced the upper shelf energy of the Charpy impact transition curve for the base metal.

Disbonding can occur at the stainless steel weld overlay/2.25 Cr-1 Mo steel interface after service exposure. Microstructure, hydrogen diffusion profiles and stress are the factors contributing to the phenomenon. The study to date has characterized the microstructure in overlay samples in the as-welded and post-weld heat treated conditions.

Studies of the kinetics of delta ferrite transformation in 316 stainless steel in the as-cast, as-welded and cold-worked states have revealed that some of the delta ferrite transforms to the chi phase as well as to the sigma phase in the as-cast and cold-worked steels, but only to the sigma phase in the as-welded condition. Work has started on the determination of the rate of transformation of delta ferrite to sigma phase in 316L and 347 stainless steel weld overlay during post-weld heat treatment.

The review of the literature on creep crack growth in Cr-1 Mo steels and the application of fracture mechanics methods have been completed and an experimental program has commenced under contract to investigate the resistance to creep crack growth in Cr/Mo steels.



An image analyzing computer, Quantimet 900, being used by B. Casault for quantitative measurements of microstructural constituents in pressure vessel weld overlay material.

420503 - WELDING PROCESS DEVELOPMENT

Project Leader - J.T. McGrath

The objective of this project is the development of welding processes for the joining of heavy wall (175-400 mm) pressure vessels.

The major part of the project is to contract the development of a commercially viable, shop proven, heavy-section welding system to the fabrication industry. The contract work will commence in 1982-83 and continue for three years. In-house activities will focus on the application of the submerged arc narrow gap welding system for welding of heavy section Cr/Mo pressure vessel steels.

420601 - DEVELOPMENT AND EVALUATION OF HIGH STRENGTH STEELS FOR OIL AND GAS PIPELINES

Project Leader - M.J. Godden

Exploitation of Canada's northern oil and gas resources will require pipelines made from controlled-rolled high-strength low-alloy (HSLA) steels with superior low temperature toughness. Recognition of this in the early 1970s resulted in extensive evaluation of overall sections of commercial linepipe from different manufacturers. This work was undertaken to establish a knowledge bank within the public sector that would be a source of impartial advice in the establishment of technically sound criteria for pipeline acceptance, and to monitor developments in linepipe steels. The evaluation of two more Grade 483 (X70) linepipes this year marks the completion of this evaluation work, although a few loose ends still remain. The evaluation has examined metallurgical uniformity and isotropy through impact and tensile properties, chemical analysis and corresponding optical quantitative microstructural analysis. Analyses of the results are not yet complete but several conclusions are now possible. Significant variations in microstructure and properties have been observed within a single section of linepipe, demonstrating the need for defining test locations precisely. Important correlations between toughness and microstructure have been shown for both ductile and cleavage fracture modes. The former correlates well with an inclusion factor having components of mean inclusion length and mean inclusion spacing; whereas the latter correlates well with the largest polygonal ferrite grain size. Recent analysis of these results has focused on the relationship between delamination frequency in Charpy specimens tested at various temperatures and microstructural features.

The unique PMRL facilities for steel melting and instrumented controlled rolling have afforded the opportunity to further develop linepipe HSLA steel metallurgy in support of the Canadian pipemaking industry. Several trends have to be considered. Leaner alloy chemistries, lower processing temperatures, higher strength grades and thicker plate gauges have all demonstrated the need to tailor the steel and processing to the available equipment. Fluctuating alloy mix costs (in particular molybdenum) have shown the need for an understanding of the separate and synergistic effects of alloying elements in order that alternative chemistries may be chosen as alloy costs change. The separate and synergistic effects of chromium and vanadium are being studied on a simple pearlite-reduced steel. Mechanical property measurements are two-thirds complete on 11 different compositions. Steels have been made ready for studies of mill loads and microstructural changes occuring during roughing. At a later stage it is hoped that this work can be related to the work being done under contract by McGill University on the effects of alloying elements on the kinetics of recrystallization and precipitation. The influence of finish rolling temperature has been studied by comparing mechanical behaviour and microstructural features of plate finished at austenite temperatures with that finished in the austenite/ferrite temperature range. The through-thickness fracture properties deteriorated with the lower finish rolling temperature due to both increased ease of microcrack nucleation at inclusion arrays and to preferential cleavage crack nucleation in the large ferrite grains parallel to (001); at the lower finishing temperature, there was more pronounced (001) preferred orientation parallel to the rolling plane.

420602 - DEGRADATION, INSPECTION AND REPAIR OF PIPELINES

Project Leader - M.J. Godden

The pipeline network in Canada represents an enormous capital investment. Pipelines are subject to hazards of mechanical damage during installation and in service and to several electrochemical related degradation mechanisms whilst in service, which can result in their premature failure. Research is being conducted to ascertain what degree of mechanical damage can be accepted, what level of residual stresses can be tolerated and how the effects of electrochemical attack can be mitigated.

MECHANICAL DAMAGE

During pipelaying, dents and gouges can be produced by earth moving equipment and by rocks and debris in the trench. Experimental work on the effect of dents with different shapes and severities on fracture initiation in pipelines has been completed this year. Dents with gentle curvature can be pushed out close to their original contours during pressuring. The hoop strain can be over 15% yet no crack is initiated either during initial pressurization or subsequent fatigue loading. Dents with sharp curvature cannot be removed during proof testing and while the hoop strain is low during initial pressuring the strain concentration can be over three times larger, leading to subsequent crack initiation during fatigue testing. A theoretical elastic-plastic analysis of the state of deformation of a pipe with a dent has started. This work is the first of a wider series of studies aimed at quantifying the effects of mechanical damage on fracture initiation in pipe using the finite element method.

Flattened specimens with a machined notch or scraped gouge were tested at the start of an investigation of gouge effects. Machine notched specimens failed at the notch during both tensile and fatigue testing. Gouged specimens failed at the gouge only in fatigue tests, unless the gouge caused a thickness reduction of more than 20%, in which case they also failed in tension.

RESIDUAL STRESSES

Pipeline failure is possible through unintentional overload caused by applied stress and residual stress acting together. Residual stresses from the pipeforming and expansion operation can reach 50% of yield stress. Measurements of residual stress using different techniques have been completed this year. Residual stress measurements by strain gauge methods on commercial pipe have been summarized in a report, and a second report of stress measurements in the last spiral weld pipe to be evaluated has been written.

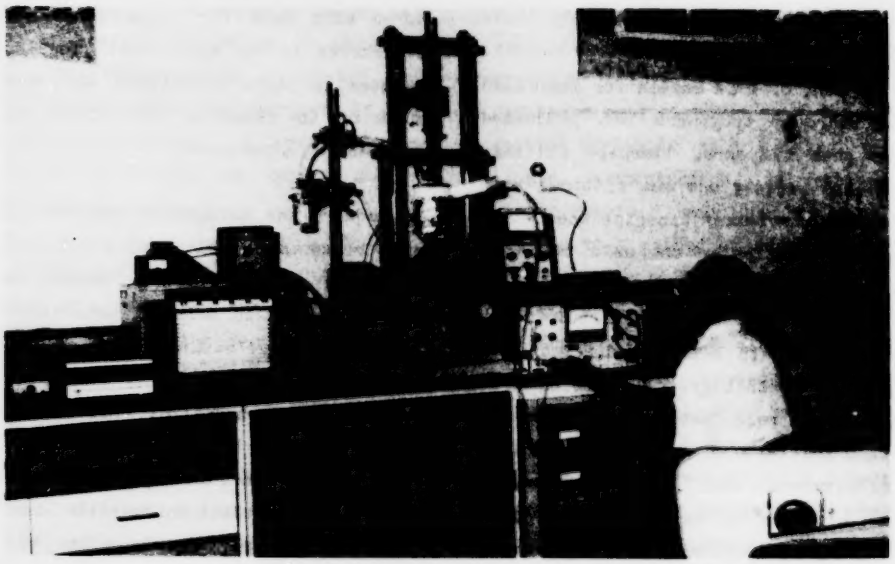
Stresses can change during pipeline service due to earth movement e.g. washouts. Queen's University is measuring the effect of stress on magnetic parameters in pipe steel under contract. Attempts will be made to correlate laboratory measurements with magnetic measurements made in the field by a pipeline company.

CORROSION DEGRADATION MECHANISMS

Linepipe steels are subject to cracking in the presence of hydrogen sulphide (H_2S) from sour oil or gas. In recent years, H_2S-induced failures have occurred in Western Canada. As pipelines age and more sour wells are brought on stream this failure mode will become increasingly important. This has lead to a collective initiative from industry resulting in share-funded research at PMRL.

Two forms of H_2S-induced cracking, sulphide stress cracking (SSC) and stepwise cracking (SWC), are under investigation. Sample testing of nine gas transmission pipes covering grades 290-483 is two-thirds completed. Standard test methods for susceptibility to SWC and SSC developed by the National Association of Corrosion Engineers are being used. The results are now being assessed to determine the operative cracking mechanisms and their relevance to sour service performance.

Stress corrosion cracking is another failure mechanism which is attributable to soil-borne ions attacking through a coating break. Using the



R. Ramsingh of the Corrosion Science Section is testing the susceptibility of linepipe steel to stress corrosion cracking by a slow strain rate technique.

slow-strain-rate tensile testing machine and teflon electrochemical cell designed and built at PMRL, the electrochemical potential ranges in which linepipe steels stress corrode in nitrate and carbonate/bicarbonate solutions at 40°C at a strain rate of 10^{-6} per second have been defined. Reports are in preparation.

420603 - FABRICATION OF PIPELINES

Project Leader - M.J. Godden

WELDING

Assessment of the properties of mill welds in commercial linepipe and the field weldability of these steels continues to be an important aspect of the commercial linepipe evaluation work. Field weldability and implant tests were done on the most recent section of spiral welded linepipe to be evaluated. The results indicated satisfactory weldability and only moderate sensitivity to hydrogen cracking in the field weld heat-affected zone, comparable to a similar steel previously tested which had no inclusion shape control. However, the seam weld metal toughness was inferior in the linepipe made from steel with sulphide shape control. This phenomenon is being further investigated.

The notch toughness of regions within the seam weld heat-affected zone is difficult to determine because the microstructure and properties change abruptly over short distances. The coarse-grained heat-affected zone (CGHAZ) is a region of particular concern because of its poor toughness. Work is continuing on the evaluation of CGHAZ toughness in commercial linepipe using the precracked instrumented impact test. Two commercial linepipe seam welds were evaluated in this way in the past year. In general the CGHAZ has a fracture initiation temperature about 40°C higher than that of the base metal, which can be mainly attributed to its coarse grain structure.

FITTINGS

While the development of HSLA steels for increased strengths and improved toughness has proceeded rapidly in the past 15 years, linepipe fittings have developed less rapidly and now fittings with properties to match the better linepipe steels are not available. In particular the weld metal of fittings is required to have a notch toughness of 40 J at -45°C at the yield stress required. Yield stresses greater than 415 MPa are difficult to obtain with present technology. A research program to investigate weld metal properties of fittings has been initiated after discussions with fittings manufacturers and welding-consumable manufacturers. A series of welds is being prepared with a range of wire/flux combinations using submerged arc welding and procedures typical of a fittings production shop. Initially the microstruture and mechanical properties of each consumable combination will be assessed in the normalized and stress relieved condition.

420604 - FABRICATION, PERFORMANCE, INSPECTION AND REPAIR TECHNOLOGY DEVELOPMENT (FOR OFFSHORE STRUCTURES)

420605 - DEVELOPMENT OF TOUGH WELDABLE STEELS (FOR OFFSHORE STRUCTURES)

Project Leader - J.B. Gilmour

These two projects will be discussed together because they are, in essence, PMRL's work on "materials for offshore structures". These projects originated during FY 1981-82 and are funded through the National Energy Program.

It is envisaged that the development of Canada's offshore (east coast and Beaufort Sea) energy reserves will require the construction of a variety of engineering structures, possibly including large semi-submersible production platforms, conventional jacket structures and steel caisson retained islands. These structures will be exposed to very severe environmental conditions including, in the Beaufort Sea, air temperatures as low as -55°C. Even the east coast air temperatures will fall far below those experienced by structures in the North Sea. Thus the steels to be used in these structures must have properties superior to those of the steels used in most engineering structures.

To acquire the background information required to plan research in this area a consultant from the United Kingdom (Prof. H.C. Cotten) was brought to PMRL to assist in defining materials problems and to present three seminars outlining his experience in the development of the North Sea hydrocarbon resources. In addition, PMRL scientists visited laboratories in Europe where much of the research on materials for offshore use has been carried out. Much needed information on fatigue and corrosion fatigue was obtained by attending a conference where the results of the European Communities five-year research program on steel in marine structures were presented.

Five contracts were initiated during the year in these projects:

(1) A review of steels used in the construction of offshore structures. The contractor was asked to review the regulations imposed by governments, classification societies and others on the steels and weldments used in offshore structures with particular emphasis on the relationship between fracture properties and service temperature.

(2) A survey of the expected demand for steel plate used for constructing offshore structures and arctic vessels. The contractor was to determine the expected demand for the various grades of thick steel plate and the ability of the Canadian steel industry to meet the demand.

(3) Corrosion fatigue of tubular joints. This contract was an extension of research on fatigued tubular joints underway at Memorial University.

(4) Canadian structural steel plate. This contract will characterize the fracture resistance of samples of four grades of Canadian produced steel to CSA standard G40.21.

(5) Design of a heavy-section fracture testing machine. It may be necessary to impact test samples of steel plate up to 75 mm thick, used in the construction of arctic ice-breaking tankers and LNG carriers as well as offshore structures. A contractor has been asked to design an impact machine having 150-kJ capacity.

In-house work during the first year of these projects consisted of a review of the finite element analysis programs used in the design of offshore structures and the development of finite element analysis techniques to describe the stress intensity at a growing fatigue crack at the weld toe in heavy plate specimens. Plans were prepared for a comprehensive fatigue and corrosion fatigue research project which may be extended to include testing of tubular joints. Other research will be undertaken on welding and weld treatment to enhance fatigue resistance, non-destructive evaluation, and on steels with excellent low temperature properties.

A shared-funding research program was formulated and advertised through the DSS bulletin. In this program industry is being asked to submit proposals in the area of steels for offshore structures and those meeting certain criteria will be 50% funded by CANMET, with the sponsoring industry paying the other 50%. By the end of the financial year expressions of interest had been received from over 20 organizations.

430901 - MATERIALS FOR COAL HANDLING AND UTILIZATION

Project Leader - A.W. Lui

Past shortages in oil supplies and numerous jumps in fuel costs have created new interest in the enormous domestic resources of coal. Previous experience with coal and coal slurry preparation, and coal conversion and utilization processes, indicates that material problems may be a major factor in the expansion of fossil energy systems.

During FY 1981-82, the wear resistance of commercial alloys, mild steel 1020, carbon steel 1062, stainless steels 304, 316, 440C and 904L and titanium alloys were studied in aerated and deaerated coal slurries as a function of environmental variables such as slurry concentration, oxygen concentration, pH and velocity. An electrochemical technique has been developed and has led to a method of determining the components of wear, erosion and corrosion. At low and intermediate velocities, the erosion component of wear of carbon steel is small, and the total wear can be significantly reduced by a corrosion control method. With cathodic protection, the wear of carbon steel at 3 m/s was reduced by 95%. Wear of Type 304 S.S. was directly proportional to coal concentration up to 10% and remained constant above this concentration. This work is now complete.

Performance of boiler materials, stainless steel Types 304, 316, 347, 904L and 310, was studied in the laboratory under simulated fluidized bed coal combustion environments. The corrosion kinetics of the alloys in a synthesized flue gas containing high sulphur and low oxygen were followed at 900°C, and the morphology of the scale deposit was studied to determine the significance of sulphidation attack. To simulate the in-bed corrosion of materials in the combustor, the alloys were also exposed to synthesized coal ash deposit in the presence of the flue gas. Results have shown that materials degradation was more severe through in-bed corrosion than by flue-gas corrossion.

430902 - MATERIALS FOR HIGH-TEMPERATURE ENERGY CONVERSION PROCESSES (NEP)

Project Leader - A.W. Lui

All advanced energy conversion processes impose severe demands on construction materials because of high temperature, high pressure, corrosive and erosive conditions. Successful economic development of these technologies will depend to a certain extent on the working materials that can

withstand these hostile operating conditions.

During FY 1981-82, three R & D contracts were undertaken:

(1) Study of corrosion and erosion of fluidized-bed coal-combustion boiler tubes. The performance of ferritic steel and austenitic steel boiler tubes was studied in an atmospheric fluidized bed combustor using high-sulphur coal. This work is now complete and a final report has been written.

(2) Protective coatings for components of fossil energy conversion systems. A plasma vapour deposition coating, TiB_2, was developed and the work is being continued.

(3) Design and construction of a high-temperature-erosion test facility. The design phase is complete and construction will start in FY 1982-83. The equipment to be built can be used to study behaviour of materials under high-temperature corrosive-erosive conditions.

PART C. PUBLICATIONS, PRESENTATIONS AND REPORTS

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MRP/PMRL 81-1(OP-J) Davis, K.G. and Magny, J.G. "Optimum ladle preheating practice with gas torches".

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MRP/PMRL 81-56(OP) Buhr, R.K. "Inoculation of grey and ductile irons".

MRP/PMRL 81-60(OP) Buhr, R.K. "New technology in grey and ductile irons".

MRP/PMRL 81-61(OP) Davis, K.G. "Microstructure, heat treatment and properties of unalloyed grey and ductile cast irons".

MRP/PMRL 81-62(OP) Davis, K.G. "Alloyed and grey ductile irons".

MRP/PMRL 81-65(OP) Warda, R.D. "Cupola melting practice for grey and ductile iron".

MRP/PMRL 81-66(OP) Whiting, L.V. "Ferrous foundry sand practice".

ERP/PMRL 81-71(OP) Sastri, V.S. Beaupré, R. and Desgagne, M. "Studies on molybdate as pipeline corrosion inhibitor in coal water slurries".

MRP/PMRL 80-65(TR) Fegredo, D.M., Ng-Yelim, J., Kiff, D.R. and Connors, E.F. "Reference microstructures obtained by isothermally transforming three rail steels (standards C-Mn, Cr-Mo and Mn-V) at various temperatures".

ERP/PMRL 80-76(TR) Saiddington, J.C. "Corrosive and abrasive wear of linepipe and abrasive resistant steels in Quartz-tailing slurries".

MRP/PMRL 80-80(TR) Chandel, R.S. and Hoare, R. "Effect of the process variables on the bead geometry of the submerged arc strip overlay welds".

ERP/PMRL 80-82(TR) Sastri, V.S. "Studies on the effect of some oxygen scavengers on the caking properties of metallurgical coals".

MRP/PMRL 80-83(TR) Brigham, R.J. "Corrosion resistant reinforcement in concrete part 2 CANMET program".

ERP/PMRL 80-84(TR) Godden, M.J. "Microstructural aspects of the seam weld heat-affected zone of linepi: AE".

MRP/PMRL 80-87(TR) Crawley, A.F., Ruddle, G.E. and Linkletter, D. "Rolling mill load requirements for some experimental dual-phase steel compositions".

MRP/PMRL 80-88(TR) McDonald, R.D. and Ramsingh, R. "Corrosion of sheet steel by an intermittent immersion method effect of temperature and humidity".

ERP/PMRL 80-91(TR) Shehata, M.T. "Techniques for characterizing grain structure in HSLA steels".

ERP/PMRL 81-2(TR) Parsons, D.E. and Munro, D.A. "Examination of four coal cutter picks".

MRP/PMRL 81-7(TR) Biefer, G.J. and Garrison, J.G. "Long-term atmospheric corrosion tests of carbon and weathering steels at Ottawa and in the Arctic".

MRP/PMRL 81-9(TR) Sahoo, M. and Edwards, J. "Foundry characteristics mechanical properties and weldability of both Nb and Cr modified high-strength 70/30 cupro-nickel alloys".

MRP/PMRL 81-10(TR) Knight, R.F. "Microstructure and hardness of experimental direct-quenched and commercial abrasion-resistant steels".

MRP/PMRL 81-11(TR) Parsons, D.E. and Munro, D.A. "Mechanical properties developed by reheat-treatment of 150 mm (6-in.) length of alloy rail".

MRP/PMRL 81-12(TR) Sastri, V.S. "Studies on the absorption spectra of metal ion complexes and their use as oxygen scavengers".

MRP/PMRL 81-14(TR) Dion, J.L. "Preliminary experiment on mold variables for thin-walled aluminum sand castings".

ERP/PMRL 81-18(TR) Hoey, G.R. and Bednar, J.S. "Erosion/corrosion of AISI C1020, type 304 and 440C alloys and Ni-hard cast iron in coal water slurries".

MRP/ERP/PMRL 81-21(TR) Erickson, W.H., Jubb, J.T. and White, D.W.G. "Research laboratory annual report for fiscal year 1980-81".

MRP/PMRL 81-25(TR) Buhr, R.K. "Energy conservation in the foundry industry".

MRP/PMRL 81-30(TR) Brigham, R.J. "Corrosion resistant reinforcement in concrete part 3: Metallography of corroded rebar".

MRP/PMRL 81-31(TR) Shehata, M.T. and Casault, B.R. "The microstructures of some as-hot-rolled dual phase steels".

ERP/PMRL 81-39(TR) Biefer, G.J., Fichera, M. and Selwyn, J. "Stepwise cracking tests of linepipe in H_2S environments".

MRP/PMRL 81-47(TR) Lagowski, B. "The causes and prevention of 'Black spots' in Mg-Zr castings".

INTERNAL AND CONFIDENTIAL REPORTS

(not for inclusion in the open file)

ERP/PMRL 81-4(INT) Lui, A.W. "A research proposal on performance of boiler materials during FBC of coal".

MRP/PMRL 81-24(INT) Nilmani, M. "Electroslag casting at the University of British Columbia".

MRP/PMRL 81-26(INT) Packwood, R.H., Moore, V.E. and Chartrand, V.C. "Green dust".

ERP/PMRL 81-32(INT) Kiff, D. and Tyson, W.R. "Summary of residual stress measurements on linepipes".

MRP/PMRL 81-37(INT) Cousineau, E. and Mitchell, C.M. "Determination of corrosion compounds on zinc coated specimen".

MRP/PMRL 81-38(INT) Cousineau, E. and Mitchell, C.M. "Corrosion compound on reinforcement bar for concrete".

ERP/PMRL 81-50(INT) Tyson, W.R. and Knight, R.F. "Temper embrittlement of experimental 2-1/4 Cr-1 Mo plate steels".

ERP/PMRL 81-51(INT) Fichera, M.J. "Procedures used for stepwise cracking research at PMRL".

ERP/PMRL 81-58(INT) Selwyn, J.C. "Determination of diffusible hydrogen at 45°C in stepwise cracking measurements on linepipe steels".

MRP/PMRL 81-64(INT) Harbec, J. "Elastic plastic fracture toughness test techniques".

MRP/PMRL 81-72(INT) Caron, V.L. and Newbury, J. "Nondestructive procedures for the inspection of propane tank cars, (type 95 or 96 underframe)".

ERP/PMRL 81-76(INT) Kiff, D. and Tyson, W.R. "Residual stress measurements on linepipe AG".

MRP/PMRL 81-77(INT) McDonald, R.D. "The status of welding in ship building. A report on welding practices in Canadian shipboard".

ERP/PMRL 82-2(INT) Hoey, G.R. and Bednar, J.S. "Progress report on erosion/corrosion studies".

MRP/PMRL 82-3(INT) Lagowski, B. "Optimum properties in magnesium alloy sand casting".

MRP/PMRL 80-25(CF) Packwood, R.H. and Parsons, D.E. "Examination of wires showing 'Zebra' marks".

MRP/PMRL 80-33(CF) Chartrand, V.C. and Packwood, R.H. "An energy dispersive X-ray spectrometer examination ` deposits in two gas turbines".

MRP/PMRL 81-1(CF) Newbury, J. "Nondestructive examination of the shaft of a British American bank note impression cylinder number 680-1054".

MRP/PMRL 81-2(CF) Knight, R.F. "Examination of gas turbine engine guide vanes".

MRP/PMRL 81-3(CF) Dion, J.L. "Examination of a failed copper fuel line from the scene of a fire in Bathurst, N.B.".

MRP/PMRL 81-4(CF) Parsons, D.E. and Munro, D.A. "Examination of failed Cr-Cb rail samples 1, 2, 3".

ERP/PMRL 81-5(CF) Revie, R.W. and Fichera, M. "Stepwise cracking of Ipsco linepipe".

MRP/PMRL 81-7(CF) Brigham, R.J. and Emmett, J.R. "Investigation of failed superheater tube".

MRP/PMRL 81-8(CF) Knight, R.F. "Comparison of materials used in the manufacture of cold-formed steel sheet piling".

MRP/PMRL 81-9(CF) Tyson, W.R., Vosikovsky, O., McGrath, J.T. and Caron, V. "Failure analysis of Guy Anchor Plate".

MRP/PMRL 81-10(CF) Dion, J.L. "Examination of a 9.5-mm (3/8-in.) diam copper fuel line from the scene of a house fire in Caraquet, N.B.".

MRP/PMRL 81-11(CF) Parsons, D.E. and Munro, D.A. "Failure of hold-down clamp used during hydrostatic testing of HMCS preserver boilers".

MRP/PMRL 81-12(CF) Szabo, E.I. and Gauthier, R. "Foundry evaluation Avonlea bentonite".

MRP/PMRL 81-13(CF) Knight, R.F. and Ayers, G. "Examination of drum pilot valve feathers".

MRP/PMRL 81-14(CF) Sahoo, M., Barry, J.T. and Kleinschmidt, K. "Examination of experimental welds on fittings of cast 90/10 Cu-Ni".

MRP/PMRL 81-15(CF) Parsons, D.E., Munro, D.A. and Packwood, R.H. "Metallurgical examination of burst superheater tubes from No. 6 Foster-Wheeler boiler, Clift St., Central Heating Plant, Public Works, Canada".

MRP/PMRL 81-17(CF) Parsons, D.E. and Munro, D.A. "Metallurgical examination of failed dead bolt, crane-block assembly".

MRP/PMRL 82-1(CF) Sahoo, M., Barry, J.T. and Kleinschmidt, K. "Examination of Cu-Ni tubes from AECL".

MRP/PMRL 82-2(CF) Sahoo, M. and Kleinschmidt, K. "Examination of copper roll-bond absorber".

DECLASSIFIED CONFIDENTIAL REPORTS

MRP/PMRL 78-39(CF) Warda, R.D. "Measurement of particulate emissions from the Prasco high-temperature emission control (HITEC) system at Thor-Foundry, Winnipeg".

MRP/PMRL 79-11(CF) Trudeau, L.P. "Viewing of fractured tanker 'Kurdistan' in St. John, N.B. April 16-17, 1979".

MRP/PMRL 79-37(CF) Gilmour, J.B. and Blouin, A. "Examination of a corroded keel kooler".

ERP/PMRL 81-6(CF) Brigham, R.J. "Investigation of the Kars chimney failure".

REPORTS BY CATEGORY

Publications	29	Confidential and Internal Reports	34
Available PMRL Reports	52	Declassified Confidential Reports	5

PART D. STAFF ACTIVITIES

1981-82 CONFERENCE ATTENDANCE

Boyd, J.D. Thermomechanical Processing of Microalloyed Austenite, Pittsburgh, Pennsylvania, August 16-20, 1981.

Boyd, J.D. Advances in Physical Metallurgy and Applications of Steel, Liverpool, England, September 21-25, 1981.

Caron, V. Annual Conference of the American Society for Nondestructive Testing, Atlanta, Georgia, October 11-16, 1981.

Cousineau, E., Fegredo, D.M., Mitchell, C.M. and Tyson, W. 31st Canadian Metal Physics Conf., Kingston, Ontario, June 2-5, 1981.

Crawley, A.F. AIME Spring Meeting, Dallas, Texas, February 14-18, 1981.

Crawley, A.F, Hoey, G.R., McDonald, R.D., McGrath, J.T., Revie, R.W., Ruddle, G.E., Vosikovsky, O. and White, D.W.G. CIM Conference of Metallurgists, Hamilton, Ontario, August 23-27, 1981.

Davis, K.G., Sahoo, M., Warda, R.D. and Whiting, L.V. AFS Conference, Cincinnati, Ohio, April 26-May 1, 1981.

Gilmour, J.B. Fracture Problems and Solutions in the Energy Industry Conference, Winnipeg, Manitoba, September 2-4, 1981.

Gilmour, J.B., McGrath, J.T., Vosikovsky, O. and White, D.W.G. International Conference on Steel in Maritime Structures, Paris, France, October 5-8, 1981.

Godden, M. Conference on Steels for Linepipe and Pipeline Fittings, London, England, October 16-23, 1981.

McGrath, J.T. MICON 82 Conference, Houston, Texas, January 17-20, 1982.

Lui, A.W. Conference on Corrosion Erosion-Wear of Materials in Fossil Energy Systems, Berkley, California, January 26-29, 1982.

Milliken, K. 1981 Spring Digital Equipment Corporation Users' Society U.S. Symposium, Miami, Florida, May 17-21, 1981.

Milliken, K. and Mitchell, C.M. XII Congress of the International Union of Crystallography, Ottawa, Ontario, August 14-25, 1981.

Ng-Yelim, J. Electron Microscope Society of Canada Conference, Montreal, Quebec, July 15, 1981.

Packwood, R. Microbeam Analysis Society Conference, Vail, Colorado, July 12-18, 1981.

Revie, R.W. Electrochemical Society Fall Conference, Denver, Colorado, October 14-17, 1981.

Ruddle, G.E. ISS (AIME) 23rd Mechanical Working and Steel Processing Conference, Pittsburgh, Pennsylvania, October 27-29, 1981.

Sahoo, M. ICE TECH 81 Conference, Ottawa, Ontario, June 17-19, 1981.

Sastri, V.S. International Conference on Slurry Transportation, Lake Tahoe, Nevada, March 21-28, 1981.

Shehata, M.T. 1981 International Metallographic Society Conference, San Francisco, California, July 18-23, 1981.

Szabo, E.I. Annual Technical Conference of the Investment Casting Institute, Scottsdale, Arizona, October 14-17, 1981.

Tyson, W.R. Gordon Research Conference on Physical Metallurgy, Andover, New Hampshire, July 5-10, 1981.

Tyson, W.R. 2nd International Symposium on Elastic-Plastic Fracture Mechanics, Philadelphia, Pennsylvania, October 4-9, 1981.

FIELD TRIPS AND SIGNIFICANT MEETING TRAVEL

J.R. Barry

Collected cooling curve data on propeller castings at Canadian Stone Marine Ltd., Iberville, Quebec, May 6-7, 1981.

Collected PMRL equipment and cooling data at Canadian Stone Marine Ltd., Iberville, Quebec, May 11, 27-28 and June 1-2, 1981.

Visited Canadian Stone Marine Ltd. to install thermocouples in a propeller mould, Iberville, Quebec, August 18, 1981.

Monitored cooling of propeller, cast at Canadian Stone Marine Ltd., Iberville, Quebec, September 1-2, 1981.

R.M. Beaupré

Visited Alcan Laboratories Facility for hydrogen in metals determination, Kingston, Ontario, June 26, 1981.

G.J. Biefer

Participated in the activities of National Association of Corrosion Engineers Test Group, Toronto, Ontario, April 5-8, 1981.

Discussed ultrasonic measurements with Alcan Research, Kingston, Ontario, September 9, 1981.

Participated in NACE Fall Committee week meetings, Denver, Colorado, September 20-22, 1981.

Attended Corrosion Control Committee of the Canadian Gas Association, Edmonton, Alberta, October 21-23, 1981.

Attended meetings of Technical Committee T-1F and Task Group T-1F T-1F-17 and T-1F20, Houston, Texas, March 22-25, 1982.

J.D. Boyd

Attended CSIRA Meeting, Hamilton, Ontario, June 18-21, 1981.

Attended seminar on Cumulative Damage, Hamilton, Ontario, December 2, 1981.

Visited COMINCO to discuss future research activities on Zn-base alloys, Mississauga, Ontario, February 5, 1982.

Visited Noranda Research Centre to discuss future research work on Zn-Al alloys, Pointe Claire, Quebec, February 16, 1982.

Visited University of Toronto to discuss recent steel making advances, Toronto, Ontario, February 23, 1982.

Visited Theta Industries and MMC Inc. to examine dilatometers, New York, N.Y., February 24-26, 1982.

D.C. Briggs

Visited Queen's University to view and dis-

cuss a fluid bed combustor and thermal analysis equipment, Kingston, Ontario, March 18, 1981.

Visited McMaster University to discuss high temperature materials for energy conversion system, Hamilton, Ontario, September 2, 1981.

Visited Electic Power Research Institute to discuss high temperature materials for energy conversion systems, Palo Alto and Berkley, California, September 14-18, 1981.

Attended meeting of Sub-committee 9 on Coal Gasification of the Metal Properties Council, San Antonio, Texas, October 27-29, 1981.

R.J. Brigham

Visited Husky Oil and Canadian Liquid Air to discuss localized corrosion of stainless steel in in-situ recovery, Calgary, Alberta, December 9-10, 1981.

R.K. Buhr

Attended Annual General Meeting of the Canadian Foundry Association, Montreal, Quebec, May 11-12, 1981.

Visited foundries in Calgary, Alberta, to discuss advances made in technology, September 24-27, 1981.

Attended meeting of Ductile Iron Research Committee 12-k, Des Plaines, Illinois, October 12-13, 1981.

Visited SCRATAI in Sheffield U.K., and Russell Bros. in Leicester, U.K.; visited European Common Market Countries and participated in an Iron Foundry Mission, Sheffield, England, October 27-November 14, 1981.

Visited ORF to discuss Mould Flux Research Contract, Mississauga, Ontario, December 18, 1981.

Visited foundries in London, Stratford and Cambridge, Ontario, in relation to permanent moulding research, February 2-3, 1982.

V. Caron

Attended meetings of CSNDT Foundation Executive Board, Hamilton, Ontario, October 22-23, 1981.

Attended meeting of the Long Term Planning Committee of the CSNDT Foundation, Toronto, Ontario, November 3, 1981.

Visited The Welding Institute of Canada to discuss contract research on NDT of pressure vessels, Oakville, Ontario, November 24, 1981.

Visited Ahuntsic College to discuss the status of nondestructive training in Montreal, Quebec, January 6-7, 1982.

Attended meeting of Planning Committee of CSNDT Foundation, Toronto, Ontario, February 1, 1982.

Visited École Polytechnique and University of Montreal to inform students of career opportunities, Montreal, Quebec, February 9, 1982.

Visited Sherbrooke University to promote research career with CANMET through meeting university graduates and staff, Sherbrooke, Quebec, March 3-4, 1982.

G. Carpenter

Visited JEOL Inc. to evaluate TEM/STEM microscope, Peabody, Mass., January 13-15, 1982.

Visited Philips Co. to evaluate TEM/STEM microscopes and discuss general electron microscopy, Eindhoven, Holland, January 19-27, 1982.

Visited McMaster University to discuss TEM/STEM microscopy, Hamilton, Ontario, March 15, 1982.

B. Casault

Visited Cambridge Instruments to observe operation of Quantimet 900 microscope, Monsey, New York, October 14-15, 1981.

L. Collins

Visited Theta Industries and MMC Inc. to examine dilatometers, New York, N.Y., February 24-26, 1982.

A. Couture

Visited Canadian Stone Marine Ltd. to see the casting of bronze propellers, Iberville, Quebec, April 22, 1981.

Visited Canadian Stone Marine Ltd. to collect cooling data, Iberville, Quebec, May 27-28, 1981.

A.F. Crawley

Attended spring meeting of American Deep Drawing Research Group, Dearborn, Michigan, April 6-8, 1981.

Visited STELCO R&D Department to discuss research in cold rolling, Burlington, Ontario, April 21, 1981.

Visited DOFASCO Ltd. to discuss research in sheet metal and cold rolling, Hamilton, Ontario, May 6, 1981.

Attended a seminar on Modern Grainflow Controlled for Cold Forming of Steels, Toronto, Ontario, May 18-20, 1981.

Attended CSIRA Meeting, Hamilton, Ontario, June 18, 1981.

Attended meeting of CIM Metals Engineering Committee, Toronto, Ontario, October 2, 1981.

Attended fall meeting of American Deep Drawing Research Group, Chicago, Illinois, October 19-21, 1981.

Visited DOFASCO Ltd. to discuss research in continuous annealing, Hamilton, Ontario, October 27, 1981.

Interviewed students at University of Waterloo for "Co-op" Program positions, Waterloo, Ontario, November 17-18, 1981.

Attended a seminar on Cumulative Damage Process in Metal-Working, Hamilton, Ontario, December 2, 1981.

Attended a meeting on High Strength Sheet Steels, Detroit, Michigan, January 26-27, 1982.

Visited manufacturers of leaf springs, Chatham, Ontario, March 15-17, 1982.

K.G. Davis

Visited Canadian Steel Foundries to discuss upcoming joint presentation, Montreal, Quebec, July 14, 1981.

Visited heat-treat shop of Forano Ltd., St. Eustache, Quebec, August 21, 1981.

Gave presentation at the Tech and Operating Session, Steel Castings Institute of Canada, Montebello, Quebec, September 17-19, 1981.

Visited Queen's University to discuss upcoming workshop, Kingston, Ontario, November 24, 1981.

Visited foundries in London, Stratford and Cambridge in relation to permanent moulding research, London, Ontario, February 2-3, 1982.

Attended contract review meeting on CEA contract, Vancouver, British Columbia and visited Syncrude, Edmonton, Alberta, February 22-24, 1982.

J.L. Dion

Visited Tallman Bronze Ltd. to discuss copper tuyères casting, Burlington, Ontario, August 25-26, 1981.

K. Eastman

Visited UBC to observe and operate electroslag casting machine, Vancouver, British Columbia, January 10-15, 1982.

W.H. Erickson

Visited N. Thomas, Director of Research, DOFASCO, Hamilton, Ontario, April 10, 1981.

Attended meeting of Canadian Steel Industry Research Association, Quebec City, Quebec, April 21-22, 1981.

Made a presentation of PMRL program and discussed technology transfer with AECL, Chalk River, Ontario, April 28-29, 1981.

Attended Annual Meeting of the Canadian Foundry Association, Montreal, Quebec, May 11-12, 1981.

Visited UBC to discuss contract, met with DND re: Electroslag Casting Project, Vancouver and Victoria, British Columbia, May 19-27, 1981.

Attended Annual Business Meeting of CSNDT, Hamilton, Ontario, June 18-19, 1981.

Discussed program with Director of Research, STELCO, Hamilton, Ontario, September 30-October 1, 1981.

Attended a meeting of CSIRA, Saskatoon, Saskatchewan, October 29-31, 1981.

Discussed joint projects at Algoma Steel, Sault Ste. Marie, Ontario, December 17-20, 1981.

Meeting with Canadian University/Government Team to discuss tours/objectives, Dusseldorf, Germany, February 26-March 14, 1982.

Visited Dr. G. Bata, IMRI, NRC, Montreal, Quebec, March 29, 1982.

D.M. Fegredo

Visited Technical University of Nova Scotia to discuss contract work on worn rail steel discs, Halifax, Nova Scotia, May 14-15, 1981.

Visited UBC to discuss research on rolling and HSLA steels, Vancouver, British Columbia, October 4-6, 1981.

M. Fichera

Visited Alcan Research to discuss ultrasonic measurements, Kingston, Ontario, September 9, 1981.

J. Gianetto

Attended seminar on Submerged Arc Welding, Oakville, Ontario, March 17, 1982.

J.B. Gilmour

Visited various industrial concerns to discuss material problems in offshore structures and pipelines, Houston, Texas, May 3-7, 1981.

Meeting with representatives of the Canadian Steel Industry Research Association, Hamilton, Ontario, June 18, 1981.

Visited Memorial University and Centre for cold ocean resources engineering, St. John's, Newfoundland, July 14-16, 1981.

Visited laboratories, in London, Amsterdam, Oslo and Trondheim, September 26-October 17, 1981.

Attended Annual Meeting of the Canadian Shipbuilding and Ship Repairing Association, Montreal, Quebec, March 1-2, 1982

Discussed materials for in situ recovery of oil with Canadian Liquid Air and Husky, Montreal, Quebec, March 5, 1982.

M.J. Godden

Visited Stelco Research Labs, Hamilton, Ontario, December 14, 1981.

Visited University of Toronto to discuss recent steel making advances, Toronto, Ontario, February 23, 1982.

H.P. Guindon

Presented a workshop for Cupola Furnace Operators in Western Canada, Edmonton, Alberta, November 12-14, 1981.

Presented a workshop in Cupola Operation, Moncton, New Brunswick, November 18-22, 1981.

Visited Forano Ltd. to discuss issuing a contract for the study of the Influence of Tuyère Performance on Cupola Performance, Plessisville, Quebec, January 13-15, 1982.

Presented a Cupola Workshop, Cambridge, Ontario, January 21-24, 1982.

Presented a Cupola Workshop, Cambridge, Ontario, February 18-21, 1982.

Presented a Cupola Workshop, Trois Rivières, Quebec, March 26-27, 1982.

G.R. Hoey

Attended a meeting of Board of Directors, METSOC, Montreal, Quebec, April 24-25, 1981.

Visited ORF to discuss erosion/corrosion in COM combustion systems, Toronto, Ontario, June 25, 1981.

Attended Committee Meeting of the Coal Liquid Mixture Working Group, Halifax, Nova Scotia, December 14-16, 1981.

Visited NRC Atlantic Regional Laboratory to discuss wear of materials by coal slurries, Halifax, Nova Scotia, March 8-9, 1982.

J.T. Jubb

Visited Manitoba Rolling Mill, International Steel Pipe Corp., Manitoba, Saskatchewan and Alberta, May 19-21, 1981.

Visited Waterloo University to interview candidates for Co-op work term, Waterloo, Ontario, June 16, 1981.

Attended CSIRA meeting and visited STELCO Research Labs, Hamilton, Ontario, June 18-19, 1981.

Visited NRC-IMRI to discuss NDT research, Montreal, Quebec, September 17, 1981.

Discussed program with Director of Research, STELCO, Hamilton, Ontario, October 1, 1981.

Visited the Welding Institute of Canada to discuss contract research on NDT of pressure vessels, Oakville, Ontario, November 24, 1981.

Discussed joint projects at Algoma Steel, Sault Ste. Marie, Ontario, December 17, 1981.

Visited Ontario Hydro to discuss future direction of CCISW, Toronto, Ontario, January 28, 1982.

Visited University of Toronto to discuss recent steel making advances, Toronto, Ontario, February 23, 1982.

D. Kiff

Visited Ontario Hydro to discuss similar strain gauge techniques used to measure residual stresses, Toronto, Ontario, July 10, 1981.

R.F. Knight

Visited Falconbridge Nickel Mines Limited to discuss abrasion-resistance tests, Thornhill, Ontario, November 8-9, 1981.

Attended CSA Technical Committee (Structural Steel) Meeting, Richmond Hill, Ontario, May 20-21, 1981.

W. Koch

Visited Dofasco Ltd. to discuss research in

continuous annealing, Hamilton, Ontario, October 27, 1981.

B. Lagowski

Visited CORBRON Foundry to discuss improvements in the production of castings in magnesium alloys, Cornwall, Ontario, August 6, 1981.

Visited Haley Industries Ltd. to discuss problems encountered in Magnesium Alloy Foundry, Haley, Ontario, December 1-2, 1981.

M. Letts

Visited Iron Ore Company of Canada to register thermal cycles of an electro flash welding rail, Sept-Iles, Quebec, June 9-11, 1981.

A.W. Lui

Attended symposium on High Temperature Materials in Coal Liquification and Gasification, Oak Ridge, Tennessee, May 14-16, 1981.

Visited McMaster University to discuss high temperature materials for energy conversion system, Hamilton, Ontario, September 2, 1981.

Visited Electric Power Research Institute to discuss high temperature materials for energy conversion systems, Palo Alto and Berkley, California, September 14-18, 1981.

Visited high temperature corrosion/erosion facilities at Battelle Laboratories, Columbus, Ohio, November 9-10, 1981.

Visited Morenco Company to discuss final specifications of corrosion/erosion facility, St. Catharines, Ontario, December 15, 1981.

Attended meeting for a CEA contract at Ontario Hydro Research Labs, Toronto, Ontario, March 10, 1982.

Visited Queen's University to view and discuss a fluid bed combustor and thermal analysis equipment, Kingston, Ontario, March 18, 1982.

D. Lusk

Visited New Brunswick Research and Productivity Council to set up CGSB Examination Centre, Fredericton, New Brunswick, August 30-September 1, 1981.

J.G. Magny

Visited Stone Marine Ltd. to collect cooling curve data in propeller casting, Iberville, Quebec, May 6-7, 1981.

Visited Stone Marine Ltd. to pick up PMRL equipment and cooling data, Iberville, Quebec, May 11, 1981.

Visited Stone Marine Ltd. to collect cooling data, Iberville, Quebec, May 27-28, June 1-2, September 2 and 8, 1981.

T. Malis

Discussed analytical scientific equipment and investigative techniques with Alcan Research Lab Personnel, Kingston, Ontario, October 2, 1981.

Visited JEOL Inc. to evaluate TEM/STEM microscope, Peabody, Mass., January 13-15, 1982.

Visited Philips Co. to evaluate TEM/STEM microscopes and discuss general electron microscopy, Eindhoven, Holland, January 19-27, 1982.

Visited McMaster University to discuss TEM/-STEM microscopy, Hamilton, Ontario, March 15, 1982.

J.T. McGrath

Attended Canadian Council of International Institute of Welding Meeting, Montreal, Quebec, April 27, 1981.

Presented summary of Pressure Vessel Project at meeting of The Welding Institute, Toronto, Ontario, May 11-12, 1981.

Made a presentation at CSIRA Meeting and Pro-

ject Meeting, Burlington, Ontario, June 18-19, 1981.

Attended meeting at The Welding Institute of Canada, Toronto, Ontario, May 11-12, 1981.

Attended CSA Fracture Toughness Task Group Meeting, Toronto, Ontario, September 14, 1981.

Attended CSA Welding Sub-Committee Meeting, Toronto, Ontario, September 18, 1981.

Attended meeting at The Welding Institute to discuss progress on contracts, Toronto, Ontario, September 29-30, 1981.

Attended International Institute Welding Meeting, Toronto, Ontario, November 5, 1981.

Visited The Welding Institute of Canada to discuss contract research on NDT of pressure vessels, Oakville, Ontario, November 24, 1981.

Attended progress meetings on Market Survey Contract and Heavy Section Welding Contract, Edmonton and Calgary, Alberta, December 10-11, 1981.

Attended progress meeting on HAZ Toughness Project at STELCO, Toronto, Ontario, December 14, 1981.

Attended meeting at Canadian Liquid Air regarding development of wires for narrow gap welding, Montreal, Quebec, January 13, 1982.

Attended meeting of CIIW, Toronto, Ontario, January 14, 1982.

Attended progress meeting on external contract, Montreal, Quebec, February 12, 1982.

Attended CSA Pipeline Meeting, Vancouver, British Columbia, February 22-26, 1982.

Attended DITC Project Review Meeting at Weld Process International, Toronto, Ontario, March 31, 1982.

K. Meleskie

Visited AMDU, CFB Trenton to re-assess the practical tests for Aircraft Structures Certification, Trenton, Ontario, October 4-7, 1981.

Visited Air Canada to discuss requirements of A/S Certification, Dorval, Quebec, November 18, 1981.

K. Milliken

Interviewed student applicants for employment at University of Waterloo, Waterloo, Ontario, November 19, 1981.

Interviewed student applications for employment, Waterloo, Ontario, March 3, 1982.

C.M. Mitchell

Visited Ontario Hydro to arrange their participation in performance evaluation of portable X-ray Stress Diffractometer, Toronto, Ontario, July 20, 1981.

Visited PROTO Ltd. to discuss construction of the X-ray Stress Diffractometer, Oldcastle, Ontario, September 1, 1981.

Visited PROTO Ltd. to hold discussions about design revisions of a portable X-ray Stress Diffractometer, Windsor, Ontario, December 21, 1981.

Visited PROTO Ltd. to discuss the design of the head of a portable X-ray Diffractometer, Windsor, Ontario, March 8, 1982.

J.P. Monchalin

Visited Sidbec to discuss research needs in NDT, Contrecoeur, Quebec, February 25, 1982.

Visited manufacturer to obtain information and to examine a laser unit prior to its shipping, New York, N.Y., March 11, 1982.

J. Newbury

Attended CSNDT Ottawa Valley Chapter Meeting, Trenton, Ontario, April 24, 1981.

Visited Alcan Research Centre, Kingston, Ontario, September 9, 1981.

Visited AECL to discuss implementation of Eddy Current Practical Test, Chalk River, Ontario, December 2-4, 1981.

R.H. Packwood

Attended SCITEC Annual General Meeting, Toronto, Ontario, November 9-10, 1981.

Attended SCITEC Annual General Meeting and COPSE Meeting, Ottawa, Ontario, February 3, 1982.

Attended SCITEC Executive Meeting, Dorval, Quebec, March 8, 1982.

Attended Industrial Symposium and Industrial Affiliates Meeting, London, Ontario, March 25-27, 1982.

Z. Paley

Attended meeting of Welding Research Council, Columbus, Ohio, May 5-6, 1981.

Visited Iron Ore Co. of Canada to register thermal cycles of an electro flash welded rail, Sept-Iles, Quebec, June 9-11, 1982.

D.E. Parsons

Attended meeting on research project contract on non-leaded free machining steels, Hamilton, Ontario, October 2, 1981.

W.A. Pollard

Visited Fennell Corp. to discuss fluidized beds, Chicago, Illinois, August 18, 1981.

Discussed contract on fluidized bed cooling, Hamilton, Ontario, September 28, 1981.

Visited IC Combustion Ltd. to inspect and discuss fluidized bed, Dorval, Quebec, November 26, 1981.

R.W. Revie

Visited Trans-Canada Pipelines Ltd. to discuss pipeline inspection techniques and research requirements, Toronto, Ontario, May 14, 1981.

Attended meeting of the Canadian Council, American Society for Metals, Cincinnati, Ohio, September 21-22, 1981.

Presented a talk at the Fall Meeting of the Electroslag Society, Ottawa, Ontario, October 30, 1981.

Attended meeting at Queen's University to discuss progress on contract on Pipeline Inspection, Kingston, Ontario, November 2, 1981.

Discussion with Trans-Canada Pipelines on work being carried out at Queen's University, Toronto, Ontario, December 7, 1981.

Attended meeting of Steering Committee for International Conference on Pipeline Inspection, Edmonton, Alberta, January 17-18, 1982.

Attended meeting of Steering Committee for International Conference on Pipeline Inspection, Edmonton, Alberta, February 17-18, 1982.

Presented a paper on Stress-Corrosion Cracking at March Meeting of NACE-Toronto Section, Toronto, Ontario, March 9, 1982.

G. Roy

Visited Ontario Hydro to discuss similar strain gauging techniques used to measure residual stresses, Toronto, Ontario, July 10, 1981.

G.E. Ruddle

Visited McGill University, Montreal, Quebec, April 28, 1981.

Visited STELCO Research Centre and DOFASCO Strip Rolling Mills, Hamilton, Ontario, June 18-19, 1981.

Visited U.S. Steel Research Laboratory and University of Pittsburgh to discuss advances in thermomechanical processing of microalloyed steels, Pittsburgh, Pennsylvania, August 16-19, 1981.

Visited IVACO Rolling Mill, L'Orignal, Ontario, September 10, 1981.

Visited Department of Mechanical Engineering, Queen's University, Kingston, Ontario, December 7, 1981.

Visited STELCO R&D Centre to discuss controlled rolling requirements for TIN steel plate, Burlington, Ontario, December 14, 1981.

M. Sahoo

Visited Canadian Stone Marine Ltd. to see the casting of bronze propellers, Iberville, Quebec, April 22, 1981.

Visited Burnstein Castings regarding casting for DND, St. Catharines, Ontario, May 25, 1981.

Supervised casting of a 6-valve chest casting for DND, St. Catharines, Ontario, July 7-11, 1981.

Visited Canadian Stone Marine Ltd. to install thermocouples in a propeller mould, Iberville, Quebec, August 18, 1981.

Visited Burnstein Castings to examine the X-ray radiographs of a 6-valve chest casting, St. Catharines, Ontario, August 25-27, 1981.

Attended Brass and Bronze Research Committee Meeting, Ann Arbor, Michigan, September 24-25, 1981.

Visited Burnstein Castings to examine the X-ray radiographs of a 6-valve chest casting, St. Catharines, Ontario, October 1, 1981.

Visited Queen's University to discuss the solidification workshop for spring 1982, Kingston, Ontario, November 24, 1981.

Attended Brass and Bronze Division Meeting of the American Foundrymen's Society, Des Plaines, Illinois, January 11-12, 1982.

Attended the Regional Chapter Officer's Meeting of the American Society for Metals, Montreal, Quebec, January 19, 1982.

Visited Burnstein Castings to do pressure test on the 6-valve chest casting, St. Catharines, Ontario, February 4, 1982.

Visited COMINCO to discuss future research activities on Zn-base alloys, Mississauga, Ontario, February 5, 1982.

Visited DREA to discuss R&D co-operation and give a brief seminar, Halifax, Nova Scotia, February 11-12, 1982.

Visited Noranda Research Centre to discuss future research work on Zn Al alloys, Pointe Claire, Quebec, February 16, 1982.

V. Sastri

Visited Alcan Laboratories Facility for hydrogen in metals determination, Kingston, Ontario, June 26, 1981.

J. Selwyn

Visited Alcan Research Labs to discuss ultrasonic measurements, Kingston, Ontario, September 9, 1981.

M.T. Shehata

Visited Cambridge Instrument Company to observe the Quantimet 900 microscope in operation, Monsey, New York, October 14-15, 1981.

Visited Carl Leiss Canada Ltd. to see the functions of IBAS II Image Analyser, Toronto, Ontario, November 6, 1981.

G. Smelsky

Visited Noranda Ltd. to obtain information concerning metal forming, Montreal, Quebec, February 25, 1982.

R. Thomson

Chaired spring meeting of the Canadian Continuous Steel Casting Research Group, Whitby, Ontario, April 21-23, 1981.

Attended meeting of Canadian Continuous Steel Casting Research Group, Hawkesbury, Ontario, December 16, 1981.

W.R. Tyson

Attended CSA Meeting, Toronto, Ontario, September 15-17, 1981.

Attended meeting of CFM Material Engineering Section, Toronto, Ontario, October 2, 1981.

Presented seminar on Mechanical Properties of Dual-Phase Steels, Hamilton, Ontario, November 25-26, 1981.

Attended workshop on Cumulative Damage, Hamilton, Ontario, December 2, 1981.

Attended CSA Committee Meeting and visited UBC, Vancouver, British Columbia, February 21-27, 1982.

Participated in meeting of ASM International Metals Review Committee, Cleveland, Ohio, March 29-30, 1982.

O. Vosikovsky

Visited Memorial University and Centre for Cold Ocean Resources Engineering, St. John's, Newfoundland, July 14-16, 1981.

Visited various laboratories, London, Amsterdam, Oslo and Trondheim, September 26-October 17, 1981.

Visited WIC Oakville and TSI Toronto to examine the results of corrosion fatigue tests, Oakville, Ontario, January 29, 1982.

R.D. Warda

Presented a Workshop for Cupola Furnace Operators in Western Canada, Edmonton, Alberta, November 12-15, 1981.

Presented a Workshop in Cupola Operation, Moncton, New Brunswick, November 18-22, 1981.

Visited ORF to discuss Mould Flux Research Contract, Mississauga, Ontario, December 18, 1981.

Travelled to Stephens-Adamson Foundry to observe cupola operation and advise on improvements, Belleville, Ontario, January 6, 1982.

Discussed issuing a contract for The Study of the Influence of Tuyère Performance on Cupola Performance, Plessisville, Quebec, January 13-15, 1982.

Presented a Cupola Workshop, Cambridge, Ontario, January 21-24, 1982.

Attended a workshop on the Use of Microcomputers in the Foundry, Milwaukee, Wisconsin, February 9-12, 1982.

Presented a Cupola Workshop, Cambridge, Ontario, February 18-21, 1982.

Presented a Cupola Workshop at Mohawk College, Hamilton, Ontario, March 11-12, 1982.

Presented a Cupola Workshop, Trois Rivières, Quebec, March 26-27, 1982.

D.W.G. White

Arranged participation of Ontario Hydro in performance evaluation of portable X-ray Stress Diffractometer, Toronto, Ontario, July 20, 1981.

Discussed construction of the head, and design and construction of the mount of the X-ray Stress Diffractometer, Oldcastle, Ontario, September 1, 1981.

Visited McMaster University to discuss research on non-leaded free machining steels, Hamilton, Ontario, November 10, 1981.

Attended meeting of Committee for Needed Research on Northern Pipelines, Montreal, Quebec, December 14, 1981.

Visited PROTO Ltd. to hold discussions about design revisions of a portable X-ray Stress Diffractometer, Windsor, Ontario, December 21, 1981.

Visited Defence Research Establishment Atlantic to discuss R&D cooperation and give a seminar, Halifax, Nova Scotia, February 11-12, 1982.

Held conversations concerning the duties and the prospects for research of Dr. Hindam at IMRI, Montreal, Quebec, February 17, 1982.

Discussed the design of the head of a portable X-ray Diffractometer, PROTO Ltd., Windsor, Ontario, March 8, 1982.

PMRL GRANT AND MONITORING ACTIVITIES (1981-82)
DESIGNATED SCIENTIFIC AUTHORITIES AND LIAISON OFFICERS

SA/LO	Funding Org/Value (81-82)	Performer	Project
J.D. Boyd	CANMET $36,600	Chinook Fuel Innovations Ltd.	Survey of requirements for plate steels in offshore structures & arctic vessels
J.D. Boyd	CANMET $22,000	Price Waterhouse Assoc., Toronto	Survey to determine the potential demand for direct quenched plate steels relevant to the Canadian steel industry
J.D. Boyd	CANMET $22,000	J.D. Embury, McMaster Univ.	Scanning transmission electron microscopy studies of HSLA steels
G.J. Biefer	CANMET $10,000	Caproco Corrosion Prevention Ltd., Edmonton, Alta.	Underground corrosion of water pipes in Canadian cities
D.C. Briggs	CANMET $60,000	Not awarded	Evaluation of stress-rupture properties of stainless steel in fluidized combustion environments
R.J. Brigham	CANMET $20,000	Dearborn Environmental Consulting Services	Evaluation of the crevice corrosion susceptibility of an austenitic stainless steel

R.K. Buhr	EMR/PILP $45,000	Dominion Eng. Works Ltd.	Degradable sand and core binders. Delayed to 1982-83
R.K. Buhr	CANMET $18,268	Davis Engineering Consulting Engineers	Servo-mechanism design & control system for thin-wall electroslag casting production
R.K. Buhr	CANMET $5,000	Dr. A. Mitchell Univ. of B.C.	Personal service contract - electroslag casting
R.K. Buhr	CANMET $20,000	Delayed to 1982-83	Foundry sand survey
V. Caron	CANMET $14,955	Welding Institute of Canada	State-of-the-art review of NDE techniques for on-line inspection of pipe-line cracks
V. Caron	CANMET $44,405	Welding Institute of Canada	To develop automated UT system for defects (Phase II)
V. Caron	CANMET $50,000	Not awarded	Detection of defects in HS welds by automated UT system (Phase III)
A.F. Crawley	CANMET $56,400	McMaster Univ.	Microstructural features which limit formability in mass produced cold forgings
A.F. Crawley	CANMET $36,200	McMaster Univ.	Microchemistry & transformation kinetics of experimental batch annealed dual-phase steels
K.G. Davis	CANMET $9,000	Univ. of Ottawa Dept. of Mechanical Engineering	Mathematical modelling of heat flow in permanent moulds
K.G. Davis	EMR/PILP $6,800	Industrial Marine Products	Field evaluation of CAN-COAT abrasion resistant dragger shoes

D.M. Fegredo	CANMET $10,000	Tech. U. of N.S. E.E. Laufer	Transmission electron microscopy of the effects of simulated rail loading on an experimental premium rail steel
J.B. Gilmour	CANMET $39,200	Det Norske Veritas Calgary	Steels used in the construction of offshore structures
M.J. Godden	CANMET $118,300	Queen's University D.L. Atherton	Investigation of the effects of mechanical stress on the magnetic properties of pipeline steels for pipeline stress monitoring
R.F. Knight	CANMET $20,000	Falconbridge Nickel Mines Ltd.	Determination of abrasion resistance of experimental plate steels
A.W. Lui	CANMET $75,000	Montreal Eng. Co. St. Catharines, Ont.	Design construction & testing of a high temperature erosion test facility
J.T. McGrath	CANMET $28,000	Welding Institute of Canada	Study of weld cracking in 2.25 Cr-1140 steels
J.T. McGrath	CANMET $20,000	Dr. A. Mitchell Univ. of B.C.	Fabrication of pressure vessel nozzles
J.T. McGrath	CANMET $35,000	Dr. B. Patchett Univ. of Alberta	Welding of heavy section pressure vessel steels by narrow gap process
J.T. McGrath	CANMET $34,650	Chinook Fuel Innovations	Market survey of pressure vessel requirements for synthetic fuel production systems
J.T. McGrath	CANMET	Contract to be awarded	Weld process development for fabrication of heavy wall pressure vessels
J.T. McGrath	CANMET $50,000	Tektrend International Ltd.	Development of on-line accoustic emission monitoring system for welding thick walled vessels

J.T. McGrath	CEA	Ontario Hydro Res.	Thermal fatigue resistance of welds
J.T. McGrath	IRAP	Steel Co. of Canada	Line 1026
J.T. McGrath	IRAP	Dominion Bridge	Groove 1124
J.T. McGrath	EMR/RAP	Profs. McLean and Weatherly, U. of T.	Gas/metal/slag reactions during arc welding
D.E. Parsons	CANMET $5,500	McMaster Univ. Prof. D.A.R. Kay	Non-leaded free-machining steels
W.A. Pollard	EMR/PILP $8,000	Algoma Steel Corp. Ltd.	Feasibility study of fluidized bed technology to the production of improved shaped products
G.E. Ruddle	EMR $19,700	CSIRA (E. Leaver, Private Consultant Willowdale, Ont.)	Quality control sensors to improve energy conservation in steel mills
G.E. Ruddle	CANMET $44,684	J.J. Jonas, McGill University	The effects of Mo, Ti & Nb on the hot working (controlled rolling) of line-pipe steels
G.E. Ruddle	CANMET $2,147	J.J. Jonas, McGill University	The effects of Nb & Mo on the hot working of line-pipe steels
G.E. Ruddle	CANMET $28,342	J.J. Jonas, McGill University	Prevention of duplex grain structures in control rolled HSLA steel
M. Sahoo	DND $68,030	Burnstein Casting St. Catharines	High integrity cupro-nickel castings for technology demonstration
M. Sahoo	CANMET $15,510	Welding Institute of Canada	The production & control of ozone in the welding of high-strength copper-base alloys
W.R. Tyson	CANMET $25,900	Ontario Research Foundation	Fracture resistance characterization of Canadian steels

W.R. Tyson	CANMET $76,322	Saskatchewan Research Council	Design of heavy-section fracture testing machine
W.R. Tyson	CANMET $79,020	D. Wilkinson McMaster Univ.	Materials & design for resistance to crack growth by creep Phase II
W.R. Tyson	IRAP	Dominion Eng. Works	GMR 1139
W.R. Tyson	IRAP	Amca International Ottawa, Ontario	Local 1154
D.W.G. White	DND $35,000	PROTO Mfg. Windsor	Develop a prototype portable X-ray Stress Diffractometer
D.W.G. White	CANMET $50,000	EG&G (Canada)	Redesign & construct a pair of more compact position sensitive detectors
D.W.G. White	PILP $100,000	Not awarded	Repackage & condense diffractometer analysis & control system
L.W. Whiting	CANMET/NRC/ DSS	Ontario Research Foundation	Protective coatings for components of fossil energy conversion systems

PMRL PROJECT LEADERS

Localized Corrosion	360001	R. Brigham
Corrosion of Steels in Soils	360002	G.J. Biefer
Corrosion Resistant Steel Reinforcement in Concrete	360003	V.M. Malhotra
Atmospheric Corrosion Testing	360004	R.W. Revie
Abrasion Resistant Cast-on Coatings	360011	R.K. Buhr
Abrasion Resistant Plate Steels	360012	R.F. Knight
Welding Mechanics	360021	J.T. McGrath
Repair and Reclamation by Welding	360022	J.T. McGrath
Heat Affected Zone Toughness	360023	J.T. McGrath
Characterization of Weld Defects	360031	O. Vosikovsky

Plastic Flow, Fracture and Stress Analysis	360041	W.R. Tyson
X-Ray Stress Diffractometer	360042	D.W.G. White
Microstructural Effects on Strength and Toughness in Engineering Alloys	360051	J.D. Boyd
Development on Non-leaded, Free Machining Steels	360052	D.E. Parsons
Cost Recovery in Materials Development Technology	360081	W.H. Erickson
Exploratory Foundry Research	370001	R.K. Buhr
Technology for the Metal Casting Industry	370002	R.K. Buhr
Degradable Sand and Core Binders	370003	R.K. Buhr
Continuous Casting of Metals	370004	R.K. Buhr
Permanent Mould Casting	370005	R.K. Buhr
Electroslag Casting	370006	R.K. Buhr
Fracture Toughness of Cast Materials	370007	R.K. Buhr
CANMET Foundry Newsletter	370008	R.K. Buhr
Optimization of Rolling Mill Performance	370011	A.F. Crawley
Influence of Microstructure on Formability	370012	A.F. Crawley
Fluidized Bed Cooling	370014	A.F. Crawley
Heat Treated Rail	370021	D.W.G. White
Automotive Materials	370031	A.F. Crawley
Marine Materials	370041	J.B. Gilmour
High Strength Copper Base Alloys for Shipboard Systems	370042	M. Sahoo
Development of Instrumentation and Techniques	380012	R.H. Packwood
Certification of NDT Personnel	380021	V. Caron
Materials for Tar Sands Processing	420501	A. Lui
Pressure Vessels	420502	J.T. McGrath
Welding Process Development	420503	J.T. McGrath
Develop and Evaluate High Strength Steels for Oil and Gas Pipelines	420601	M.J. Godden
Degradation, Inspection and Repair of Pipelines	420602	M.J. Godden
Fabrication of Pipelines	420603	M.J. Godden
Fabrication, Performance, Inspection and Repair Technology Development	420604	J. Gilmour
Tough Weldable Steels	420605	J. Gilmour
Materials for Coal Handling and Utilization	430901	A. Lui
Materials for High Temperature Energy Conservation Processes	430902	A. Lui

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

INTERNATIONAL CONFERENCE ON PIPELINE INSPECTION STEERING COMMITTEE

	(chairman)	R.W. Revie

INTERNATIONAL INSTITUTE OF WELDING

Canadian Council		(vice chairman)	J.T. McGrath
Commission X, Residual Stress, Stress Relieving Brittle Fracture		(chairman)	J.T. McGrath

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

Canadian Advisory Committee			
ISO/TC17/SC4,	Heat Treated Alloy and Free-Cutting (steels)	(members)	R.K. Buhr D.E. Parsons
SC6,	Methods of Mechanical Testing	(chairman)	D.E. Parsons
SC7,	Test Methods other than Mechanical	(member)	D.E. Parsons
SC11,	Steel Castings	(secretary)	D.E. Parsons
		(member)	V. Caron
SC15,	Rail Steels	(member)	D.E. Parsons
TC25,	Cast Iron	(member)	R.K. Buhr
TC79,	Light Metals and their Alloys	(member)	P.J. Todkill
TC111/SC1	Technical Committee on Chain	(member)	R.K. Buhr
TC135/SC7	NDT Personnel Qualification International Secretariat	(secretary)	V. Caron
TC155,	Nickel and Nickel Alloys	(member)	M.J. Lavigne
TC156/WG1	Corrosion of Metals and Alloys/Terminology	(member)	G.J. Biefer
TC164,	Mechanical Testing of Metals	(chairman)	P.J. Todkill
		(member)	A.F. Crawley
		(member)	O. Vosikovsky

XIIIth CONGRESS AND GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF CRYSTALLOGRAPHY

Commercial Exhibits Committee	(chairman)	C.M. Mitchell
Crystallographic Studies at Controlled Pressure	(co-chairman)	C.M. Mitchell

Micro Symposium on New Detectors	(co-chairman)	K.S. Milliken
Non-Commercial Exhibit Committee	(chairman)	C.M. Mitchell
	(member)	K.S. Milliken
Organizing Committee	(member)	K.S. Milliken
	(member)	C.M. Mitchell
Renaissance of Powder Diffraction	(co-chairman)	C.M. Mitchell

INTERNATIONAL JOURNAL OF PRESSURE VESSEL AND PIPING

Editorial Board	(member)	J.T. McGrath

9th INTERNATIONAL CONGRESS ON METALLIC CORROSION TECHNICAL PROGRAM COMMITTEE (member) W.R. Revie

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Departmental Representative to the Interdepartmental Committee, Committee for Scientific and Technological Policy — V. Caron

UNITED STATES OF AMERICA

AMERICAN DEEP DRAWING RESEARCH GROUP

(member) A.F. Crawley

AMERICAN FOUNDRYMEN'S SOCIETY

Editorial Board of Int. Cast Metals Journal		R.K. Buhr
Brass and Bronze Division		M. Sahoo
Ductile Iron Division Research Committee	(secretary)	R.K. Buhr
Computer Applications Committee	(member)	R.D. Warda

AMERICAN SOCIETY FOR METALS

Ottawa Valley Chapter	(vice-chairman)	R.W. Revie
	(asst. secretary -treasurer)	M. Sahoo
	(secretary -treasurer)	J.T. McGrath

AMERICAN SOCIETY FOR TESTING AND MATERIALS

E-9,	Fatigue	(member)	O. Vosikovsky
E-24,	Fracture Testing of Metals	(member)	O. Vosikovsky
E-28,	Mechanical Testing	(member)	P.J. Todkill
E-07.02.01	Magnesium Alloys	(chairman)	B. Lagowski

E-24.04.05	Task Group on Fatigue Crack Growth Rate Testing in Aqueous Environments	(member)	O. Vosikovsky

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Resistant Metallic Materials for Oil Field Equipment	(member)	G.J. Biefer
Task Group T-1F-9, Metallic Materials Testing Techniques for Sulphide Corrosion Cracking	(member)	G.J. Biefer
Task Group T-1F-17, Sulphide Stress Cracking Data by the NACE Tensile Test Procedure	(member)	G.J. Biefer
Task Group T-1F-20, Stepwise Cracking of Pipeline Steels	(member)	G.J. Biefer
Unit Committee T-1F, Metallurgy of Oil Field Equipment	(member)	G.J. Biefer
Unit Committee T-3N, Corrosion by De-icing Salts	(member)	R.D. McDonald

WELDING RESEARCH COUNCIL

High Alloys Committee	(member)	M.J. Lavigne
Sub-Committee on Corrosion Resistance	(member)	M.J. Lavigne
Sub-Committee on Heat Resistant Alloys	(member)	M.J. Lavigne
Weldability Committee	(member)	Z. Paley

CANADIAN - FEDERAL

CANADIAN ARMED FORCES CORROSION PREVENTION COMMITTEE

Ottawa Sub-Committee	(member)	J.B. Gilmour

CANADIAN ELECTRICAL ASSOCIATION

Hardfacing in Coal-Fired Power Stations	(member)	K.G. Davis

CANADIAN GOVERNMENT SPECIFICATIONS BOARD

48-GP Nondestructive Testing	(member)	V. Caron
52-GP Specifications for Major Kitchen Equipment	(member)	R.D. McDonald
53-GP Shears	(member)	D.E. Parsons

CANMET

Committee on Environment Improvement	R.K. Buhr

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Beaufort Sea Artificial Island Technical Advisory Committee	(member)	J.B. Gilmour

TRANSPORT CANADA		
Ship Plate Committee	(member)	D.E. Parsons
Propeller Castings Committee	(member)	D.E. Parsons
Interdepartmental Automobile R&D Panel		
Technical Sub-Committee	(member)	A.F. Crawley
Research Agreements Program	(coordinator for CANMET)	A.F. Crawley

CANADIAN - MISCELLANEOUS

THE ASSOCIATION OF THE SCIENTIFIC ENGINEERING AND TECHNOLOGICAL COMMITTEE OF CANADA	(honorary chairman)	R.H. Packwood
CANADIAN COMMITTEE FOR RESEARCH ON THE STRENGTH AND FRACTURE OF MATERIALS	(member of board)	W.R. Tyson
CANADIAN GAS ASSOCIATION		
Corrosion Control Committee	(member)	G.J. Biefer
CANADIAN INSTITUTE OF MINING AND METALLURGY		
Editorial Board	(member)	J.D. Boyd
Materials Engineering Committee	(member)	W.R. Tyson
	(secretary -treasurer)	A.F. Crawley
Metallurgical Society, Corrosion Section	(secretary -treasurer)	R.D. McDonald
	(chairman)	G.R. Hoey
Ottawa Branch	(chairman)	W.H. Erickson
CANADIAN STANDARDS ASSOCIATION		
Cast Iron	(member)	R.K. Buhr
Fracture Toughness Task Group	(member)	J.T. McGrath
Lead and Lead Alloys	(member)	A. Couture
Nickel and Nickel Alloys	(member)	M.J. Lavigne
Pipe Line Material	(member)	W.R. Tyson
Properties of Materials	(member)	W.R. Tyson
Steel Castings	(member)	D.E. Parsons
Steel Chain	(member)	R.K. Buhr
Steel Line Pipe for Research	(member)	W.R. Tyson
Structural Steel	(member)	R.F. Knight
Welding Sub-Committee	(member)	J.T. McGrath
Zinc and Zinc Alloys	(member)	A. Couture
CANADIAN SOCIETY FOR NONDESTRUCTIVE TESTING FOUNDATION		
Executive Member and Board Trustee		V. Caron
Board Trustee		W.H. Erickson

COMMITTEE ON COPPER CASTINGS FOR THE CANADIAN STEEL INDUSTRY COMMITTEE	(chairman)	R.K. Buhr
THE ELECTROCHEMICAL SOCIETY INC.		
Ontario-Quebec Section	(treasurer)	R.W. Revie
JOINT STEEL COMPANY PROJECT		
Technical Advisory Committee on Sheet Steels	(member)	A.F. Crawley
SPECTOGRAPHY SOCIETY OF CANADA		
Task Committee for Reference Materials Project		R.D. McDonald
OTTAWA VALLEY ELECTRON BEAM GROUP	(co-chairman)	R.H. Packwood
UNIVERSITY OF WESTERN ONTARIO		
Surface Science Laboratory, Board of Directors	(member)	R.H. Packwood

PART E. TECHNOLOGY EXCHANGE

Partial list of companies, government agencies, universities, and research organizations with which PMRL has been associated during FY 1981-82.

INDUSTRY

A

AIMCO	St. Catharines, Ont.
AMCA International	Montreal, Que.
Alberta Rockwool Corporation	Calgary, Alberta
Alcan Canada Limited	Kingston, Ont.
Algoma Steel	Sault Ste. Marie, Ont.
Alloy Foundry	Merrickville, Ont.
American Bureau of Shipping	Toronto, Ont.
Ampco Metals	Milwaukee, Wis.
Ardiem Inc. Corp.	Vancouver, B.C.
Associated Foundry	Surrey, B.C.
Atlas Steel	Welland, Ont.

B

Babcock & Wilcox	Cambridge, Ont.
Battelle Columbus Laboratories	Columbus, Ohio
Bethlehem Steel Corporation	Pittsburgh, PA
Bethlehem Steel Corporation	Bethlehem, PA
Beynon, Bacon & Donaldson	Vancouver, B.C.
British Steel Corporation	Middlesborough, Eng.
Burnstein Castings Ltd.	St. Catharines, Ont.

C

Canadair	Montreal, Que.
Canadian Carborundum	Niagara Falls, Ont.
Canadian Liquid Air	Montreal, Que.
Canadian Rockwell	Toronto, Ont.
Canadian Stone Marine Ltd.	Iberville, Que.
Canatom Inc.	Montreal, Que.
Caproco Limited	Edmonton, Alta.
Carondelet Coke Corp.	Cincinnati, Ohio
Chinook Fuel	Calgary, Alta.
Combustion Engineering	Ottawa, Ont.
Cominco Ltd.	Mississauga, Ont.
Corbron Foundry	Cornwall, Ont.
Corrosion Service Co. Ltd.	Toronto, Ont.
Crown Pump	Hamilton, Ont.

D

Davis Engineering	Ottawa, Ont.
Dee Foundry Inc.	Houston, Texas
Dofasco	Hamilton, Ont.
Dominion Bridge	Toronto, Ont.
Dominion Bridge	Montreal, Que.
Dominion Bridge	Ottawa, Ont.
Dominion Engineering Works	Montreal, Que.

E

Eastern Ontario School of Trucking	Ottawa, Ont.
Eastern Steel Casting	l'Orignal, Ont.
Eastern Tool Bits	Sydney, N.S.
Eldorado Nuclear	Ottawa, Ont.
Enterprise Foundry	Sackville, N.B.

F

Foote Minerals Ltd.	Eaton, PA
Forano Limited	Plessisville, Que.
Ford Motor Co.	Detroit, Michigan
Forinta Canada Corp.	Ottawa, Ont.

G

GSW Limited	Toronto, Ontario
General Motors	St. Catharines. Ont.
Glidden Co.	Toronto, Ont.
Godard, Hugh Consultant	Bath, Ontario
Gulf Canada Ltd.	Sheridan Park, Ont.
Gulf Canada Resources Limited	Calgary, Alta.
Gulf Oil Canada Ltd.	Toronto, Ont.

H

Halland Stavert Ltd.	Charlottetown, P.E.I.
Hambro International (Structures) Ltd.	Ottawa, Ontario
Highreld Steel and Vanadium Corp. Ltd.	London, England
Holmes Foundry	Sarnia, Ontario

I

ICE Combustion Systems Inc.	Dorval, Quebec
INCO	Toronto, Ontario
International Paint Co.	Montreal, Quebec

J

John Deere & Co.	Welland, Ont.
Johns Scientific	Toronto, Ont.

K

Kelsey Hayes Fdy.	Woodstock, Ont.

L

Lake Ontario Steel	Whitby, Ont.
Lee Valley Tools	Ottawa, Ont.
Leaver, E.W.	Willowdale, Ont.
London, Township of	London, Ont.
Lynchburg Fdy.	Lynchburg, Va.

M

Madis Engineering	Calgary, Alta.
Metallurgical Consultants Inc.	Houston, Texas
Micromedia Ltd.	Toronto, Ont.
MEFOS	Lulea, Sweden
Morris Co.	Yorkton, Sask.
Moulin Yamaska	Longueil, Que.
MPB Technologies	Montreal, Que.
McLean M. Assoc.	Calgary, Alta.

N

Nippon Steel	Kimitsu, Japan
Noranda Research Centre	Pointe Claire, P.Q.
Northern Telecom	Kingston, Ont.
NOVA	Calgary, Alta.

O

Ontario Hydro	Toronto, Ont.

P

Palmer, J.D. Assoc. Engineering Ltd.	London, Ontario
Pfizer Canada Ltd.	Montreal, Que.
Presto Castings	Glendale, Ariz.

R

RMD Technical Services	Montreal, Que.
Reliable Castings Corp.	Cincinnati, Ohio
Republic Steel Corp.	Buffalo, N.Y.
Robert Mitchell	Montreal, Que.

S

Shell Canada	Toronto, Ont.
Sherritt Research Centre	Fort Saskatchewan, Alberta
Sidbec-Dosco	Contrecoeur, P.Q.

Slater Steel	Burlington, Ont.
Solar Temp. Systems Ltd.	London, Ont.
Sonco Steel Tubing	Brampton, Ont.
Sovereign Castings Ltd.	Calgary, Alta.
Specialty Chemical Co.	Vancouver, B.C.
Specialty Steels	Mississauga, Ont.
Steel Company of Canada (STELCO)	Burlington, Ont.
Steel Company of Canada	Hamilton, Ont.
Steel Company of Canada	Windsor, Ont.
Steel and Engine Products Ltd.	Liverpool, N.S.
Steelflow Inc.	Okotoks, Alta.
Sydney Steel Corp.	Sydney, N.S.
Stevens-Adamson	Belleville, Ont.

T

Thermo Scan Engineering Ltd.	Red Deer, Alta.
Thyssen Canada	Toronto, Ont.
Toronto Iron Works	Toronto, Ont.
Trans Canada Pipelines	Toronto, Ont.

U

Union Carbide	Toronto, Ont.
Union Screen Plate	Lennoxville, P.Q.

V

Vada Industries Ltd.	Calgary, Alta.
Varateck Corp.	London, England
Vickers Canada	Montreal, Que.
Victoria Machining Depot	Victoria, B.C.

W

Wagner Castings	Decator, Illinois
Welmet	St. Catharines, Ont.
Woods Gordon Consultants	Toronto, Ont.
Wotherspoon Foundry	Oakville, Ont.

GOVERNMENT DEPARTMENTS AND AGENCIES

A

Agriculture Canada	Ottawa, Ontario
Alberta Research Council	Calgary, Alta.
Atomic Energy Control Ltd.	Chalk River, Ont.

C

Canada Customs	Ottawa, Ontario
Canadian National Railways	Montreal, Que.
Canadian Pacific Railways	Montreal, Que.
Canadian Transport Commission	Ottawa, Ont.

D

Defence Research Establishment Atlantic	Halifax, N.S.

F

Fisheries and Oceans, Department of	Burlington, Ont.

I

Indian & Northern Affairs, Dept. of	Ottawa, Ontario
Industry, Trade and Commerce, Dept. of	Ottawa, Ontario

L

Labour, Ministry of,
Gov't of Ontario — London, Ont.

N

National Defence,
Department of — Ottawa, Ont.
National Energy Board — Ottawa, Ont.
National Research
'ouncil (IMRI) — Montreal, Que.
National Research
Council — Ottawa, Ont.
National Research
Council — Vancouver, B.C.

P

Petro Canada — Calgary, Alta.
Public Works Canada — Ottawa, Ontario

R

Revenue Canada
Customs and Excise — Ottawa, Ont.
Royal Canadian Mint — Ottawa, Ont.

S

Solicitor General,
Department of — Ottawa, Ont.
Supply and Services
Canada — Ottawa, Ont.

T

Transport Canada,
Department of — Ottawa, Ont.

UNIVERSITIES AND OTHER ORGANIZATIONS

A

ASM-Advisory
Technical Awareness
Council — Cleveland, Ohio
American Foundrymen's
Society — Des Plaines, Ill.

C

CSIRA — Burlington, Ont.
Canadian Copper &
Brass Development
Association — Toronto, Ont.
Canadian Standards
Association — Toronto, Ont.
Concordia University — Montreal, Que.

E

École Polytechnique — Montreal, Que.

I

ILZRO — New York, N.Y.
Iron and Steel
Institute of Japan — Tokyo, Japan

L

Laval University — Quebec City, P.Q.

M

Memorial University — St. John's, Nfld.

McGill University — Montreal, Que.
McMaster University — Hamilton, Ont.

N

NACE — Chicago, Ill.
NACE — Houston, Texas
National Bureau of Standards — Boulder, Colorado
New Brunswick Research and Productivity Council — Fredericton, N.B.
Nova Scotia Technical College — Halifax, N.S.

O

Ontario Research Foundation — Mississauga, Ont.
Ottawa University — Ottawa, Ont.

Q

Queen's University — Kingston, Ont.

R

Research & Productivity Council — Fredericton, N.B.

S

St. Francis Xavier University — Antigonish, N.S.
Simon Fraser University — Vancouver, B.C.

T

Texas A&M University — College Sta., Texas

U

U.S. Corps of Engineers — Washington, D.C.
University of Alberta — Edmonton, Alta.
University of British Columbia — Vancouver, B.C.
University of New Brunswick — Fredericton, N.B.
University of Sherbrooke — Sherbrooke, P.Q.
University of Toronto — Toronto, Ont.
University of Waterloo — Waterloo, Ont.
University of Windsor — Windsor, Ont.

W

Welding Institute of Canada — Oakville, Ont.
Wright State University — Dayton, Ohio

PART F. PROFESSIONAL STAFF

W.H. Erickson	B.Sc., M.Sc. (Mich. Tech.), Ph.D. (Durham), P.Eng.	Director

METAL PROCESSING LABORATORY

J.T. Jubb	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Manager
Foundry Section		
R.K. Buhr	B.Eng. (McGill)	Section Head
K.G. Davis	B.Sc. (Birmingham), M.A.Sc., Ph.D. (U.B.C.)	Res. Sci.
J.L. Dion	B.A.Sc. (Montreal) P.Eng.	Phys. Sci.
B. Lagowski	B.Sc., M.Sc. (Polish Univ. London)	Res. Sci.
E.I. Szabo	M.Sc., Ph.D. (Nottingham)	Res. Sci.
R.D. Warda	B.A.Sc. (U.B.C.), Ph.D. (Cambridge)	Res. Sci.
L.V. Whiting	B.Sc., M.Sc., Ph.D. (McGill) MBA Ottawa Univ.	Res. Sci.
R. Thomson**	B.Sc., ARCST, Ph.D. (Glasgow)	Res. Sci.
Metal Forming Section		
A.F. Crawley	B.Sc., Ph.D. (Glasgow) P.Eng.	Section Head
D.L. Baragar	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
W.A. Pollard	B.Sc., A.R.S.M. (London) P.Eng.	Res. Sci.
G.E. Ruddle	B.A. Sc., M.Sc. (Waterloo) D.Sc. (Virginia) P.Eng.	Res. Sci.
Nondestructive Testing Section		
V.L. Caron	B.A.Sc. (Laval), M.Eng. (Paris) P.Eng.	Section Head
Welding Section		
J.T. McGrath	B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.	Section Head
R. Chandel	B.E. (NAGPUR), Ph.D. (Birmingham)	Res. Sci.
Z. Paley	B.Sc., M.Sc., (Haifa), Ph.D. (McGill)	Res. Sci.
R.D. McDonald	B.Sc., (Queen's), P.Eng.	Res. Sci.

**Seconded to Program Office

METAL DEVELOPMENT LABORATORY

D.W.G. White	S.M., Sc.D. (M.I.T.), P.Eng.	Manager

Corrosion Science Section

J.B. Gilmour	B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.	Section Head
G.J. Biefer	B.Sc., Ph.D. (McGill)	Res. Sci.
R.J. Brigham	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
G.R. Hoey	B.Sc., M Sc., Ph.D. (Toronto)	Res. Sci.
A.W. Lui	B.Sc., M.A.Sc., Ph.D. (Windsor)	Res. Sci.
D.C. Briggs	B.Eng., M.Eng. (McGill), Ph.D. (Queen's)	Res. Sci.
R.W. Revie	B.Eng. (McGill), M.Eng. (R.P.I.) Ph.D. (M.I.T.)	Res. Sci.
J.C. Saiddington	Chem. Eng., M.A.Sc. (Toronto)	Res. Sci.
V.S. Sastri	B.Sc., M.A., Ph.D. (State U of N.Y.)	Res. Sci.

Engineering and Metal Physics Section

W.R. Tyson	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Section Head
R. Bell*	B.Sc., Ph.D. (Queen's Belfast) P.Eng.	Res. Sci.
G. Carpenter	B.Sc., Ph.D (Wales)	Res. Sci.
E.J. Cousineau	B.Sc. (Carleton)	Phys. Sci.
J. Harbec	B.Eng. (McGill), P.Eng.	Phys. Sci.
K.S. Milliken	B.Sc. (Queen's)	Res. Sci.
C.M. Mitchell	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
J. Ng-Yelim	B.A. (Carleton), B.Sc. (Ottawa U.)	Phys. Sci.
R.H. Packwood	B.Sc., Ph.D. (Birmingham)	Res. Sci.
G. Roy	M.Sc. (Silesian), Ph.D. (P.A.M.)	Res. Sci.
P.J. Todkill	B.A.Sc. (Toronto)	Eng.
O. Vosikovsky	B.A.Sc., Ph.D. (Prague)	Res. Sci.
K.C. Wang	B.A.Sc., Ph.D. (Rensselaer)	Res. Sci.
W N. Roberts**	M.A., Ph.D. (Leeds)	Res. Sci.

Metallurgy Section

J.D. Boyd	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Section Head
L. Collins	B.Sc., M.Sc. (Queen's), Ph.D. (M.I.T.)	Res. Sci.
A. Couture	B.A., B.A.Sc. (Laval), P.Eng.	Res. Sci.
D.M. Fegredo	B.Sc., M.Sc., Dipl. I.I.Sc. Ph.D. (Sheffield), M.I.M.	Res. Sci.

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* On sabbatical leave from Carleton University, Sept. 1981-June 1982

**Seconded to Program Office

M.J. Godden	B.Met., Ph.D. (Sheffield)	Res. Sci.
R.F. Knight	B.Sc., M.Sc. (Queen's)	Res. Sci.
M.J. Lavigne	B.A., B.A.Sc., Ph.D. (Laval)	Res. Sci.
T. Malis	B.Sc., M.E., M.Sc., Ph.D. (Manitoba)	Res. Sci.
D.E. Parsons	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
M. Sahoo	B.Sc., B.E. (I.I.Sc., Bangalore) Ph.D. (U.B.C.), P.Eng.	Res. Sci.
M.T. Shehata	B.Eng. (Cairo), Ph.D. (McMaster)	Res. Sci.

STAFF CHANGES

The following persons were appointed to PMRL during this period:

H.J. Appleby	CR
Dr. D.L. Baragar	SE RES
Dr. R. Bell	SE RES
Dr. G. Carpenter	SE RES
D.A. Caryle	Co-op Student
Dr. L.E. Collins	SE RES
Dr. R. Chandel	SE RES
S.W. Curran	Co-op Student
M. Desgagne	EG ESS
K. Eastman	ENG
P. Francois	Asst. Moulder
J.A. Gianetto	EG ESS
Y.A. Lafreniere	EG ESS
D.S. Lavigne	CR
B.E. McGuinty	ST-TYP
Dr. T.F. Malis	SE RES
Dr. J.P. Monchalin	SE RES (IMRI)
Dr. G. Roy	SE RES
C. Trinque	EG ESS

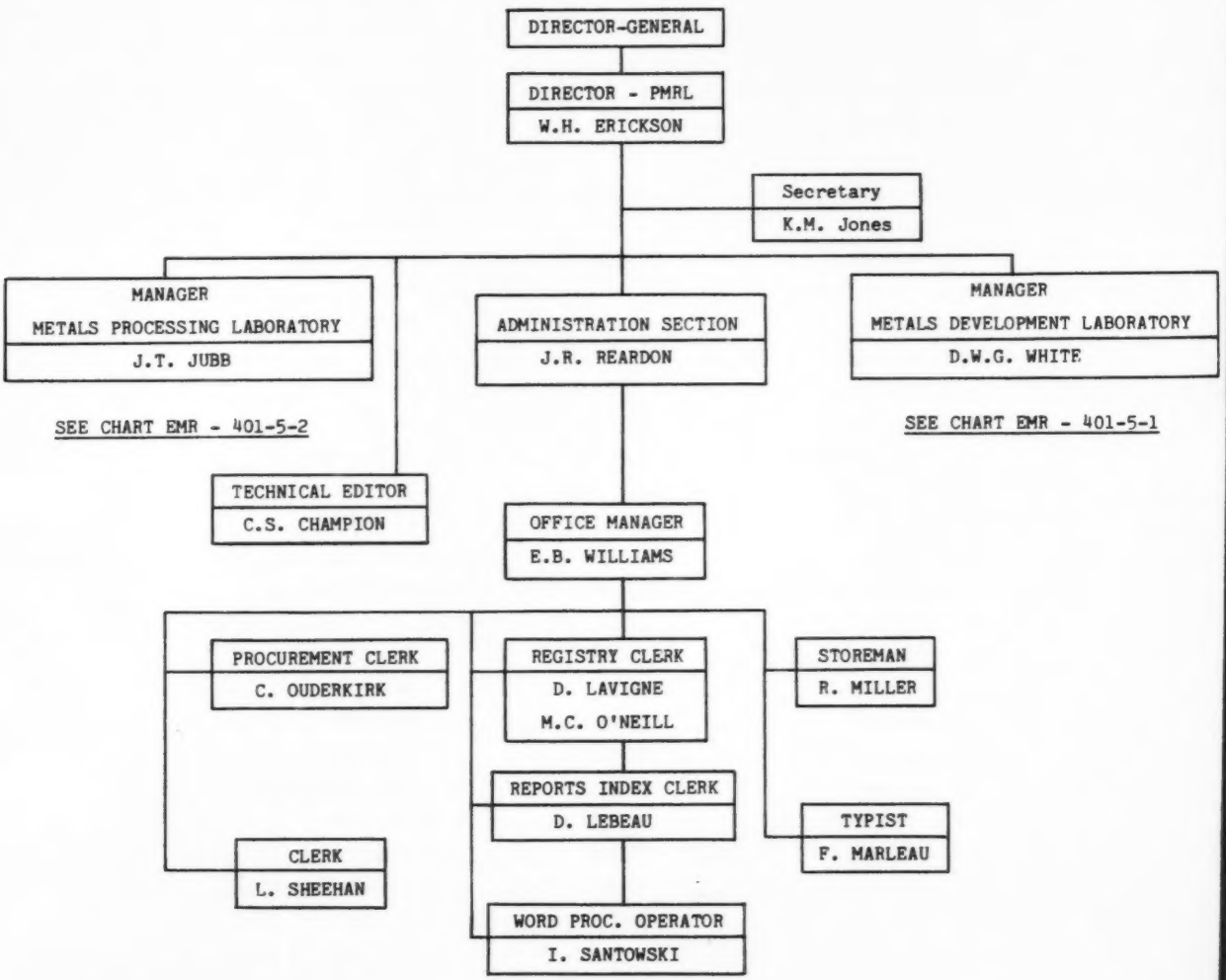
The following persons separated from PMRL during this period:

M. Desgagne	EG ESS	Transferred
K. Eastman	ENG	Resigned
J.A. Ellis	EG ESS	Retired
A. Fawcett	EG ESS	Retired
B. Lagowski	SE RES	Retired
B.E. McGuinty	ST-TYP	Resigned
M.A. Psutka	EG ESS	Transferred
J.C. Selwyn	EG ESS	Transferred
P. Todkill	ENG	Retired

CURRENT STATUS

Professionals	Non-professionals	Total
53	81	134

PMRL ORGANIZATIONAL CHARTS



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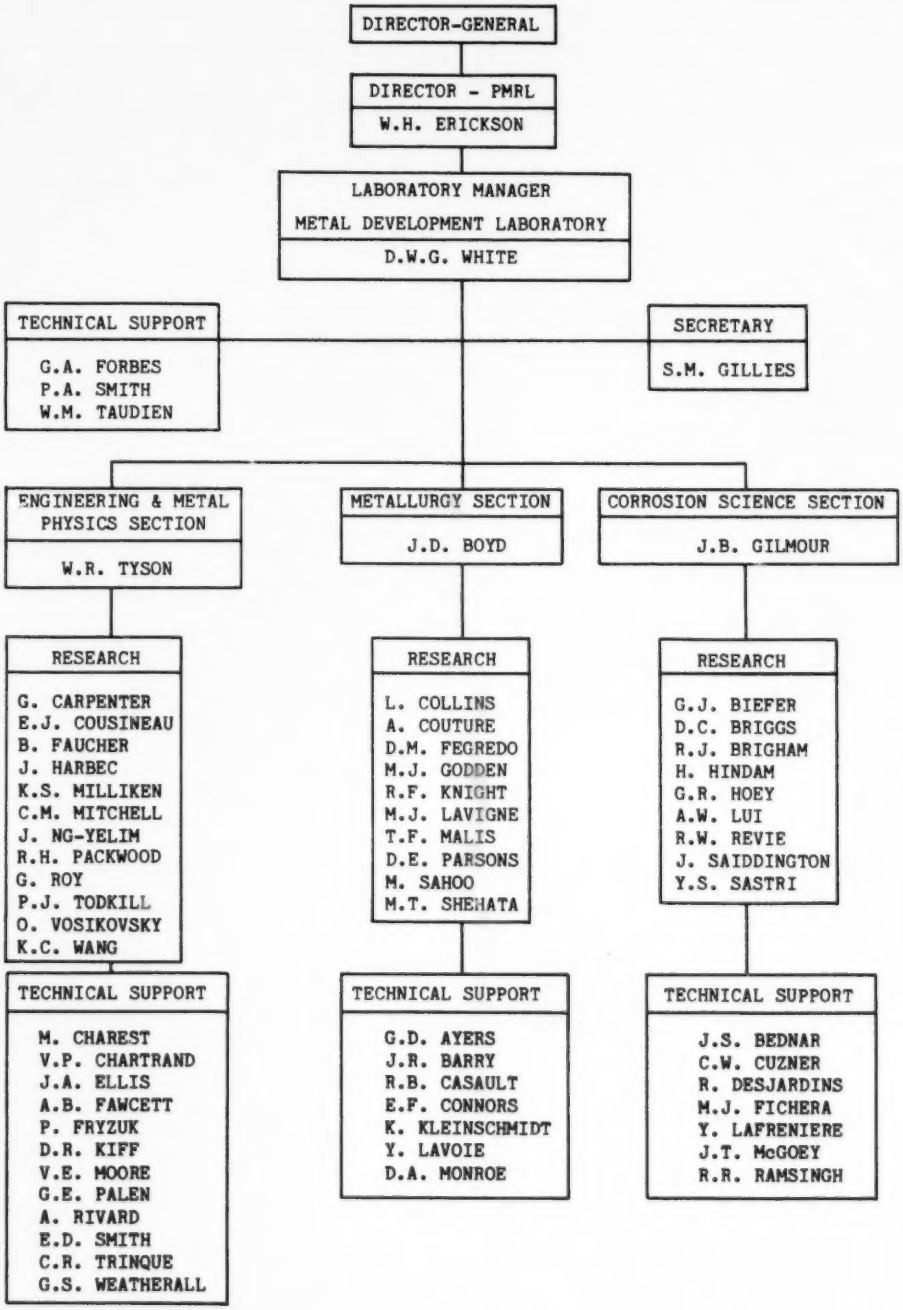

CHART EMR 401-5-2